VOLUME 172 November Supplement 2007 NUMBER 11

MILITARY MEDICINE

ORIGINAL ARTICLES

MILITARY MEDICINE, 172, 11:1, 2007

Tactical Combat Casualty Care 2007: Evolving Concepts and Battlefield Experience

Guarantor: CAPT Frank K. Butler, Jr., MC USN (Ret.)
Contributors: CAPT Frank K. Butler, Jr., MC USN (Ret.); COL John B. Holcomb, MC USA; Stephen D. Giebner, MD MPH; Norman E. McSwain, MD FACS; James Bagian, MD

The Tactical Combat Casualty Care (TCCC) project begun by the Naval Special Warfare Command and continued by the U.S. Special Operations Command developed a set of tactically appropriate battlefield trauma care guidelines that were initially published in 1996. Transition of these guidelines into use throughout the Department of Defense has been ongoing since that time. The need for updates to the TCCC guidelines was recognized early on and has been carried out by the Committee on Tactical Combat Casualty Care established and operated by the Naval Operational Medicine Institute. The evolution of these guidelines from the 1996 recommendations to the present is described. Numerous reports in the medical literature and collected from combat first responders have documented that TCCC is saving lives on the battlefield and improving the tactical flow of missions on which casualties have occurred. Present challenges to the optimized implementation of TCCC in U.S. combat units include the need to expedite transition of new TCCC techniques and technologies to deploying units, to provide TCCC training for all U.S. combatants, and to ensure adequate funding for the Committee on TCCC.

Introduction

Prehospital trauma care as performed on the battlefield differs markedly from that performed in the civilian sector. Treatment guidelines developed for the civilian setting do not necessarily translate well to the battlefield and may result in preventable deaths and unnecessary additional casualties if the tactical environment is not considered when rendering care. The austere nature of the tactical environment must be considered in developing the treatment plan. Simplicity is key. Equipment required to execute the plan must also be simple, light, and rugged.

The need for reconsideration of trauma care guidelines in the tactical setting has long been recognized (Bellamy, 1987; Baker, 1994; Heiskell and Carmona, 1994). The Tactical Combat Casualty Care (TCCC) project begun by the Naval Special Warfare Command in 1993 and later continued by the U.S. Special Operations Command (USSOCOM) developed a set of tactically appropriate battlefield trauma care guidelines that were published as a special supplement to *Military Medicine* in 1996 (Butler et al., 1996).

The recommendations in this article were somewhat at odds with civilian prehospital management strategies being taught at that time, but the advantages of having battlefield trauma guidelines optimized for the tactical setting was quickly recognized. The TCCC guidelines were first taught in 1996 in the Undersea Medical Officer course sponsored by the Navy Bureau of Medicine and Surgery (BUMED). Shortly thereafter, this training was mandated for all Navy Sea, Air, Land (SEAL) corpsmen (Richards, 1997). Since that time, TCCC gradually gained acceptance in U.S. (Allen and McAfee, 1999; Malish, 1999; Butler, 2001; DeLorenzo, 2001; Pappas, 2001) and foreign (Krausz, 1998) military forces, as well as in the civilian law enforcement medical community (McDevitt, 2001). These early transitions of TCCC were largely unit-based initiatives resulting from the individual efforts of unit medical officers and noncommissioned officers, but at this point, TCCC is standard teaching all three services' medic schoolhouses.

An important milestone in the transition process was the inclusion of the TCCC guidelines in the *Prehospital Trauma Life Support* (PHTLS) *Manual*. The fourth edition of this manual, published in 1999, contained for the first time a chapter on military medicine (McSwain et al., 1999) Preparation of this chapter was coordinated by CAPT Greg Adkisson and COL Steve Yevich at the Defense Medical Readiness Training Institute in San Antonio, Texas. The recommendations contained in the *PHTLS Manual* carry the endorsement of the American College of Surgeons Committee on Trauma and the National Association of Emergency Medical Technicians. TCCC is the only set of battlefield trauma care guidelines ever to have received this dual endorsement.

The opinions and assertions expressed by the authors are theirs alone and do not necessarily reflect the views of the Departments of the Army, Navy, or Defense.

This manuscript was received for review in July 2007 and accepted for publication in July 2007.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 NOV 2007	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Tactical combat casualty care 2007: evolving concepts and battlefield experience	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Butler Jr. F. K., Holcomb J. B., Giebner S. D., McSwain N. E., Bagian J.,	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX 78234	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**20**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The Committee on TCCC

The need for periodic updates to the TCCC guidelines was recognized early in the development of TCCC (Butler et al., 1996). There have been a number of changes made to the original guidelines in the ensuing 11 years. Some of the proposed changes originated from military medical audiences during TCCC training; others were identified during focused workshops to study real-world and hypothetical combat trauma scenarios (Butler and Smith, 1996; Bowden, 1999; Butler and Hagmann, 2000); still others came from reviews of the interim scientific and medical literature.

The 1996 TCCC article recommended that the TCCC guidelines be updated periodically by a Department of Defense-funded committee established for this purpose. In 2001, this project was presented to the USSOCOM Biomedical Initiatives Steering Committee chaired by the USSOCOM Command Surgeon, COL Dave Hammer. It was favorably endorsed and subsequently funded as a 2001 to 2002 USSOCOM biomedical research project. A key concern of the Biomedical Initiatives Steering Committee was to structure the project in such a way that it could be transitioned to one of the services later, providing for follow-on long-term support and continuation of the process beyond the research and development phase. This concern was shared by the command chosen to execute the project, the Naval Operational Medicine Institute (NOMI). As part of the planning for this effort, CAPT Doug Freer, NOMI's Commanding Officer at the time, coordinated with Navy Medicine leaders to arrange for long-term sponsorship. BUMED programmed for financial and personnel support of the Committee on TCCC beginning in fiscal year 2004. The transition from initial support by USSOCOM to permanent BUMED sponsorship was accomplished smoothly.

Since the basic principle of TCCC is to provide the best possible trauma management plan consistent with good tactics, the membership of the CoTCCC includes combat medics as well as physicians. Tri-service representation was critical to ensure that differences in doctrine and experience among the Army, Navy, and Air Force medical departments were captured. (Marine Corps combat operations are supported medically by Navy health services personnel.) The combat medics selected included SEAL corpsmen, Navy corpsmen assigned to Marine units, Ranger medics, Special Forces 18-D medics, Air Force Pararescuemen, and Air Force aviation medics. Physician membership included representatives from the trauma surgery, research, emergency medicine, critical care, and operational medicine communities. Physician assistants and combat medical educators were also represented. A list of the membership of the original CoTCCC Combat Casualty Care (a total of 28) is included in Table I. The committee membership in 2004 to 2005 is shown in Table II. Upon its transition to a permanent body, the Committee's membership was expanded to include greater rep-

TABLE I

COMMITTEE ON TCCC: 2002–2003

Chairman: CAPT Stephen Giebner	LTC Donald Jenkins
COL Robert Allen	COL Jay Johannigman
COL Frank Anders	MSG John Kennedy
CPT Steve Anderson	CPT Robert Mabry
COL James Bagian	Dr. Norman McSwain
COL Ron Bellamy	SFC Robert Miller
1LT Bart Bullock	MAJ Kevin O'Connor
CAPT Frank Butler	CAPT Edward Otten
Dr. Howard Champion	LTC Tyler Putnam
TSGT George Cum	CDR Peter Rhee
LTC Stephen Flaherty	CAPT Larry Roberts
CDR Scott Flinn	CDR Jeff Timby
MAJ John Gandy	HMCM Gary Welt
CAPT Larry Garsha	Executive Assistants:
COL John Holcomb	LT David Anderson,
Dr. David Hoyt	Ms. Shannon Addison

TABLE II

COMMITTEE ON TCCC: 2004–2005

VADM Richard Carmona	U.S. Surgeon General
SFC Brian Allen	U.S. Army Special Operations Command
MSGT Thomas Rich	Air Force Special Operations Command
MAJ Robert Mabry	2nd BN, 1st Special Forces Group
MAJ Jeffrey Cain	Army Medical Department (AMEDD)
LTCOL Kevin O'Connor	Evans Army Community Hospital
LTC Lee Cancio	U.S. Army Institute of Surgical Research
LTC Lorne Blackborne	U.S. Army Institute of Surgical Research
LTC Timothy McHenry	U.S. Army Institute of Surgical Research
LT COL Michael Curriston	Air Force Special Operations Command
LT COL John McAtee	Joint Special Operations University
LT COL Donald Jenkins	Wilford Hall Medical Center
LT David Callaway	3rd Radio Battalion, USMC
HMCS Shawn Johnson	Naval Special Warfare Development Group
HMCM Gary Welt	U.S. Special Operations Command
HMC David Johnsen	Naval Hospital Great Lakes
HM1 Michael Holmes	Bureau of Medicine and Surgery
Dr. John Hagmann	FBI
Dr. Norman McSwain	Tulane University
Dr. Howard Champion	USUHS
Dr. James Bagian	VA National Center for Patient Safety
Dr. Stephen Giebner (Chairman)	Naval Operational Medicine Institute
Dr. David Hoyt	University of California at San Diego Medical Center
Dr. Jay Johannigman	University of Cincinnati
Dr. Ronald Bellamy	Borden Institute
Dr. Edward Otten	University of Cincinatti
COL John Holcomb	U.S. Army Institute of Surgical Research
COL Robert Allen	U.S. Air Force School of Aerospace Medicine
COL Frank Anders	USASOC Surgeon's Office
CDR Russ Bowman	U.S. Coast Guard Station Sitka
CDR Ken Kelly	SEAL Delivery Vehicle Team 1
CDR Jeffrey Timby	Naval Medical Center Portsmouth
CAPT Peter Rhee	Navy Trauma Training Center
CAPT Frank Butler	U.S. Special Operations Command
CAPT Brad Bennett	Naval School of Health Sciences Portsmouth
CAPT Douglas Freer	Marine Force, Atlantic
MSGT Corey Russ	U.S. Army Special Operations Command

TABLE III

1996 TCCC GUIDELINES

Care Under Fire
1. Return fire as directed or required
2. Try to keep yourself from getting shot
3. Try to keep the casualty from sustaining additional wounds
4. Airway management is generally best deferred until the Tactical Field Care phase
5. Stop any life-threatening external hemorrhage with a tourniquet
6. Take the casualty with you when you leave

Tactical Field Care
1. Airway management
   Chin lift or jaw thrust
   Unconscious casualty without airway obstruction: nasopharyngeal airway
   Unconscious casualty with airway obstruction: cricothyroidotomy
   Cervical spine immobilization is not necessary for casualties with penetrating head or neck trauma
2. Breathing
   Consider tension pneumothorax and decompress if a casualty has unilateral penetrating chest trauma and progressive respiratory distress
3. Bleeding
   Control any remaining bleeding with a tourniquet or direct pressure
4. IV
   Start an 18-gauge IV or saline lock
5. Fluid resuscitation
   Controlled hemorrhage without shock: no fluids necessary
   Controlled hemorrhage with shock: Hespan (1,000 mL)
   Uncontrolled (intra-abdominal or thoracic) hemorrhage: no IV fluid resuscitation
6. Inspect and dress wound
7. Check for additional wounds
8. Analgesia as necessary: morphine (5 mg IV)
   Wait 10 minutes
   Repeat as necessary
9. Splint fractures and recheck pulses
10. Antibiotics
    Cefoxitin: 2 g slow IV push (over 3–5 minutes) for penetrating abdominal trauma, massive soft tissue damage, open fractures, grossly contaminated wounds, or long delays before casualty evacuation
11. Cardiopulmonary resuscitation
    Resuscitation on the battlefield for victims of blast or penetrating trauma who have no pulse, no respirations, and no other signs of life will not be successful and should not be attempted

CASEVAC Care
1. Airway management
   Chin lift or jaw thrust
   Unconscious casualty without airway obstruction: nasopharyngeal airway, endotracheal intubation, Combitube, or laryngeal mask airway
   Unconscious casualty with airway obstruction: cricothyroidotomy if endotracheal intubation and/or other airway devices are unsuccessful

(Continued)

TABLE III

CONTINUED

2. Breathing
   Consider tension pneumothorax and decompress with needle thoracostomy if a casualty has unilateral penetrating chest trauma and progressive respiratory distress
   Consider chest tube insertion if a suspected tension pneumothorax is not relieved by needle thoracostomy
   Oxygen for significantly injured casualties
3. Bleeding
   Consider removing tourniquets and using direct pressure to control bleeding if possible.
4. IV
   Start an 18-gauge IV or saline lock if not already done.
5. Fluid resuscitation
   No hemorrhage or controlled hemorrhage without shock: lactated Ringer's at 250 mL/hr
   Controlled hemorrhage with shock: Hespan (1,000 mL)
   Uncontrolled (intra-abdominal or thoracic) hemorrhage: no IV fluid resuscitation
   Head wound patient: Hespan at minimal flow to maintain infusion unless there is concurrent controlled hemorrhagic shock
6. Monitoring
   Institute electronic monitoring of heart rate, blood pressure, and hemoglobin oxygen saturation
7. Inspect and dress wound if not already done
8. Check for additional wounds.
9. Analgesia as necessary:
   Morphine (5 mg IV)
   Wait 10 minutes
   Repeat as necessary
10. Splint fractures and recheck pulses if not already done
11. Antibiotics (if not already given): Cefoxitin: 2 g slow IV push (over 3–5 minutes) for penetrating abdominal trauma, massive soft tissue damage, open fractures, grossly contaminated wounds, or long delays before casualty evacuation

resentation for the Marine Corps and representation for the Public Health Service, including the Coast Guard.

TCCC Updates 2003 and 2006

The CoTCCC has continued to monitor advances in medicine and technology as well as shifts in combat techniques and procedures. It uses such information to continually update the TCCC guidelines on a cycle matched to the publication of the PHTLS Manual. The original TCCC guidelines published in 1996 are presented in Table III. The 2003 revision of the guidelines was published in the second printing of the fifth edition of the *PHTLS Manual* (McSwain et al., 2003) as outlined in Table IV. The current guidelines were approved by the CoTCCC in 2006 and published in the sixth edition of the *PHTLS Manual* as shown in Table V (McSwain and Salome, 2006). The sixth edition includes both civilian and military versions. Although both versions contain the core PHTLS material and the latest updates to the TCCC guidelines organized into the three phases of care on the battlefield (Care Under Fire, Tactical Field Care, and Casualty Evacuation [CASEVAC] Care) described below, the mil-

TABLE IV

2003 TCCC GUIDELINES

Care Under Fire

1. Expect casualty to stay engaged as a combatant if appropriate
2. Return fire as directed or required
3. Try to keep yourself from being shot
4. Try to keep the casualty from sustaining additional wounds
5. Airway management is generally best deferred until the Tactical Field Care phase
6. Stop any life-threatening external hemorrhage:
   Use a tourniquet for extremity hemorrhage
   For nonextremity wounds, apply pressure and/or a HemCon dressing
7. Communicate with the patient if possible: offer reassurance, encouragement

Tactical Field Care

1. Casualties with an altered mental status should be disarmed immediately
2. Airway management
   Unconscious casualty without airway obstruction: chin lift or jaw thrust, nasopharyngeal airway, place casualty in recovery position
   Casualty with airway obstruction or impending airway obstruction:
   chin lift or jaw thrust, nasopharyngeal airway, place casualty in recovery position
   Surgical cricothyroidotomy (with lidocaine if conscious) if above measures unsuccessful
3. Breathing
   Consider tension pneumothorax and decompress with needle thoracostomy if casualty has torso trauma and respiratory distress
   Sucking chest wounds should be treated by applying a petroleum gauze during expiration, covering it with tape or a field dressing, placing the casualty in the sitting position, and monitoring for development of a tension pneumothorax
4. Bleeding
   Assess for unrecognized hemorrhage and control all sources of bleeding
   Assess for discontinuation of tourniquets after application of hemostatic dressing (HemCon) or a pressure dressing
5. IV
   Start an 18-gauge IV or saline lock, if indicated
   If resuscitation is required and IV access is not obtainable, use the IO route
6. Fluid resuscitation
   Assess for hemorrhagic shock; altered metal status in the absence of head injury and weak or absent peripheral pulses are the best field indicators of shock
   If not in shock: no IV fluids necessary, oral fluids permissible if conscious
   If in shock: Hextend (500-mL IV bolus), repeat once after 30 minutes if still in shock, no >1,000 mL Hextend

Continued efforts to resuscitate must be weighed against logistical and tactical considerations and the risk of incurring further casualties

If a casualty with TBI is unconscious and has no peripheral pulse, resuscitate to restore the radial pulse

(Continued)

TABLE IV

CONTINUED

7. Inspect and dress known wounds
8. Check for additional wounds
9. Analgesia as necessary
   Able to fight: Rofecoxib (50 mg po qd), acetaminophen (1,000 mg po q6 hours)
   Unable to fight: morphine (5 mg IV/IO), reassess in 10 minutes, repeat dose every 10 minutes as necessary to control severe pain, monitor for respiratory depression, promethazine (25 mg IV/IO/IM every 4 hours
10. Splint fractures and recheck pulse
11. Antibiotics: recommended for all open combat wounds
    Gatifloxacin, 400 mg po qd
    If unable to take orally (shock, unconscious, or penetrating torso injuries): cefoxitin, 2 g IV (slow push over 3–5 minutes) or IM every 12 hours
12. Communicate with the patient if possible: encourage, reassure, explain care
13. Cardiopulmonary resuscitation
    Resuscitation on the battlefield for victims of blast or penetrating trauma who have no pulse, no respirations, and no other signs of life will not be successful and should not be attempted

CASEVAC Care

1. Airway management
   Unconscious casualty without airway obstruction: chin lift or jaw thrust, nasopharyngeal airway, place casualty in recovery position
   Casualty with airway obstruction or impending airway obstruction: chin-lift or jaw-thrust, nasopharyngeal airway, place casualty in recovery position or laryngeal mask airway/ILMA or Combitube or endotracheal intubation or surgical cricothyroidotomy (with lidocaine if conscious)
   Spinal immobilization is not necessary for casualties with penetrating trauma
2. Breathing
   Consider tension pneumothorax and decompress with needle thoracostomy if casualty has torso trauma and respiratory distress
   Consider chest tube insertion if no improvement and/or long transport anticipated
   Most combat casualties do not require oxygen, but administration of oxygen may be of benefit for the following types of casualties: low oxygen saturation by pulse oximetry, injuries associated with impaired oxygenation, unconscious patient, TBI patients (maintain oxygen saturation >90)
   Sucking chest wounds should be treated with a petroleum gauze applied during expiration, covering it with tape or a field dressing, placing the casualty in the sitting position, and monitoring for the development of a tension pneumothorax
3. Bleeding
   Reassess for unrecognized hemorrhage and control all sources of bleeding
   Assess for discontinuation of tourniquets after application of hemostatic dressing (HemCon) or a pressure dressing

(Continued)

TABLE IV

CONTINUED

4. IV
   Reassess need for IV access: if indicated, start an 18-gauge IV or saline lock; if resuscitation is required and IV access is not obtainable, use IO route
5. Fluid resuscitation
   Reassess for hemorrhagic shock; altered mental status (in the absence of brain injury) and/or abnormal vital signs
   If not in shock: oral fluids permissible if conscious, IV fluids not necessary
   If in shock: Hextend (500-mL IV bolus), repeat after 30 minutes if still in shock; continue resuscitation with PRBC, Hextend, or LR as indicated
   If a casualty with TBI is unconscious and has no peripheral pulse, resuscitate as necessary to maintain a systolic blood pressure of 90 mm Hg or above
6. Monitoring
   Institute electronic monitoring of pulse oximetry and vital signs if indicated
7. Inspect and dress wound if not already done
8. Check for additional wounds
9. Analgesia as necessary
   Able to fight: Rofecoxib (50 mg po qd), acetaminophen (1,000 mg po every 6 hours)
   Unable to fight: morphine: 5 mg IV/IO, reassess in 10 minutes, repeat dose every 10 minutes as necessary to control severe pain; monitor for respiratory depression, promethazine: 25 mg IV/IO/IM every 4 hours
10. Reassess fractures and recheck pulses
11. Antibiotics: recommended for all open combat wounds
    Gatifloxacin, 400 mg po qd
    If unable to take orally (shock, unconscious, or penetrating torso injuries): IV cefotetan, 2 g IV (slow push over 3–5 minutes) or IM every 12 hours
12. MAST trousers may be useful for stabilizing pelvic fractures and controlling pelvic and abdominal bleeding. Their application and extended use must be carefully monitored. They are contraindicated for casualties with thoracic and brain injuries

itary version also contains additional chapters on the management of wounded hostile combatants, guidelines for determining the urgency of casualty evacuation, hypothermia, triage, blast injuries, and military medical ethics.

Metrics

When new medical treatment plans are proposed, an evidence-based approach to documenting the efficacy of these treatments is desirable. This evidence is uniquely hard to gather from the battlefield, however, since studies are difficult to perform in this setting, especially randomized, prospective, controlled ones. Input regarding the outcomes from TCCC practiced on the battlefield can, however, be obtained from published case reports and case series as well as lessons learned reported by first responders describing their experiences with combat trauma care. The sections below will describe how various aspects of the TCCC guidelines have evolved from 1996 to the present and present available evidence for the various aspects of care.

TABLE V

2006 TCCC GUIDELINES

Care Under Fire
1. Return fire/take cover
2. Direct/expect casualty to remain engaged as a combatant, if appropriate
3. Direct casualty to move to cover/apply self-aid if able
4. Try to keep the casualty from sustaining additional wounds
5. Airway management is generally best deferred until the Tactical Field Care phase
6. Stop life-threatening external hemorrhage if tactically feasible:
   Direct casualty to control hemorrhage by self aid if able
   Use a tourniquet for hemorrhage that is anatomically amenable to tourniquet application
   For hemorrhage that cannot be controlled with a tourniquet, apply HemCon dressing with pressure

Tactical Field Care
1. Casualties with an altered mental status should be disarmed immediately
2. Airway management
   Unconscious casualty without airway obstruction: chin-lift or jaw-thrust maneuver, nasopharyngeal airway, place casualty in recovery position
   Casualty with airway obstruction or impending airway obstruction: Chin-lift or jaw-thrust maneuver, nasopharyngeal airway: allow conscious casualty to assume any position that best protects the airway, to include sitting up; place unconscious casualty in recovery position
   If previous measures are unsuccessful, surgical cricothyroidotomy (with lidocaine if conscious)
3. Breathing
   Consider tension pneumothorax and decompress with needle thoracostomy if casualty has torso trauma and respiratory distress
   Sucking chest wounds should be treated by applying a three-sided dressing during expiration and monitoring for development of a tension pneumothorax
4. Bleeding
   Assess for unrecognized hemorrhage and control all sources of bleeding
   Assess for discontinuation of tourniquets once bleeding is controlled by other means. Before releasing any tourniquet on a patient who has been resuscitated for hemorrhagic shock, assure a positive response to resuscitation efforts (i.e. a peripheral pulse normal in character and normal mentation if there is no TBI)
5. IV
   Start an 18-gauge IV or saline lock, if indicated
   If resuscitation is required and IV access is not obtainable, use the IO route
6. Fluid resuscitation
   Assess for hemorrhagic shock; altered mental status in the absence of head injury and weak or absent peripheral pulses are the best field indicators of shock
   If not in shock: no IV fluids necessary, po fluids permissible if conscious
   If in shock: Hextend (500-mL IV bolus), repeat once after 30 minutes if still in shock, no >1,000 mL Hextend
   Continued efforts to resuscitate must be weighed against logistical and tactical considerations and the risk of incurring further casualties

(Continued)

TABLE V

CONTINUED

If a casualty with TBI is unconscious and has no peripheral pulse, resuscitate to restore the radial pulse

7. Prevention of hypothermia
   - Minimize casualty's exposure to the elements. Keep protective gear on or with the casualty if feasible
   - Replace wet clothing with dry if possible
   - Apply Ready-Heat blanket to torso
   - Wrap in Blizzard Rescue Blanket
   - Put Thermo-Lite Hypothermia Prevention System Cap on the casualty's head, under his/her helmet
   - Apply additional interventions as needed/available
   - If mentioned gear is not available, use dry blankets, poncho liners, sleeping bags, body bags, or anything that will retain heat and keep the casualty dry
8. Monitoring
   - Pulse oximetry should be available as an adjunct to clinical monitoring. Readings may be misleading in the settings of shock or marked hypothermia
9. Inspect and dress known wounds
10. Check for additional wounds
11. Analgesia as necessary
    - Able to fight: these medications should be carried by the combatant and self-administered as soon as possible after the wound is sustained: Mobic 1(5 mg po qd), Tylenol, (650 mg bilayer caplet, 2 po every 8 hours)
    - Unable to fight (have naloxone readily available whenever administering opiates):
    - Does not otherwise require IV/IO access: OTFC (800 μg transbuccally)— recommend taping lozenge-on-a-stick to casualty's finger as an added safety measure, reassess in 15 minutes, add second lozenge, in other cheek, as necessary to control severe pain; monitor for respiratory depression;
    - IV or IO access obtained—morphine sulfate (5 mg IV/IO), repeat dose every 10 minutes as necessary to control severe pain, monitor for respiratory depression; promethazine (25 mg IV/IO/IM every 4 hours, for synergistic analgesic effect, and as a counter to potential nausea
12. Splint fractures and recheck pulse
13. Antibiotics: recommended for all open combat wounds
    - If able to take po: moxifloxacin (400 mg orally qd)
    - If unable to take po (shock, unconsciousness): Cefotetan, 2 g IV (slow push over 3–5 minutes) or IM every 12 hours or Ertapenam, 1 g IV or IM every 24 hours
14. Communicate with the patient if possible
    - Encourage, reassure
    - Explain care
15. Cardiopulmonary resuscitation
    - Resuscitation on the battlefield for victims of explosion injury or penetrating trauma who have no pulse, no ventilations, and no other signs of life will not be successful and should not be attempted
16. Document clinical assessments, treatments rendered, and changes in casualty's status. Forward this information with the casualty to the next level of care

CASEVAC Care

1. Airway management
   - Unconscious casualty without airway obstruction: chin-lift or jaw-thrust maneuver, nasopharyngeal airway, place casualty in recovery position

(Continued)

TABLE V

CONTINUED

- Casualty with airway obstruction or impending airway obstruction: Chin-lift or jaw-thrust maneuver, nasopharyngeal airway—allow conscious casualty to assume any position that best protects the airway, to include sitting up, place unconscious casualty in recovery position;
- If measures above are unsuccessful—surgical cricothyroidotomy (with lidocaine if conscious) or laryngeal mask airway/ILMA or Combitube or endotracheal intubation
- Spinal immobilization is not necessary for casualties with penetrating trauma

2. Breathing
   - Consider tension pneumothorax and decompress with needle thoracostomy if casualty has torso trauma and respiratory distress
   - Consider chest tube insertion if no improvement and/or long transport anticipated
   - Most combat casualties do not require oxygen, but administration of oxygen may be of benefit for the following types of casualties: low oxygen saturation by pulse oximetry, injuries associated with impaired oxygenation, unconscious patient, TBI patients (maintain oxygen saturation >90), casualties in shock, casualties at altitude
   - Sucking chest wounds should be treated by applying a three-sided dressing during expiration and monitoring for development of a tension pneumothorax
3. Bleeding
   - Assess for unrecognized hemorrhage and control all sources of bleeding
   - Assess for discontinuation of tourniquets once bleeding is controlled by other means. Before releasing any tourniquet on a patient who has been resuscitated for hemorrhagic shock, assure a positive response to resuscitation efforts (i.e., a peripheral pulse normal in character and normal mentation if there is no TBI)
4. IV
   - Reassess need for IV access—if indicated, start an 18-gauge IV or saline lock; if resuscitation is required and IV access is not obtainable, use IO route
5. Fluid resuscitation
   - Reassess for hemorrhagic shock; altered mental status (in the absence of brain injury), and change in pulse character
   - If not in shock: no IV fluids necessary, po fluids permissible if conscious
   - If in shock: Hextend (500-mL IV bolus), repeat once after 30 minutes if still in shock, no >1,000 mL Hextend
   - Continue resuscitation with PRBC, Hextend, or LR as indicated
   - If a casualty with TBI is unconscious and has a weak or absent peripheral pulse, resuscitate as necessary to maintain a systolic blood pressure of 90 mm Hg or above
6. Prevention of hypothermia
   - Minimize casualty's exposure to the elements. Keep protective gear on or with the casualty if feasible
   - Continue Ready-Heat Blanket, Blizzard Rescue Blanket, and Thermolite cap

(Continued)

TABLE V

CONTINUED

Apply additional interventions as needed (see Table I)
Utilize the Thermal Angel or other portable fluid warmers on all IV sites if possible
Protect the casualty from wind if doors must be kept open

7. Monitoring
   Institute electronic monitoring of pulse oximetry and vital signs if indicated
8. Inspect and dress known wounds if not already done
9. Check for additional wounds
10. Analgesia as necessary
    Able to fight: Mobic (15 mg po qd), Tylenol 650 (mg bilayer caplet, 2 orally every 8 hours)
    Unable to fight (have naloxone readily available whenever administering opiates): does not otherwise require IV/IO access: OTFC (800 μg transbuccally)—recommend taping lozenge-on-a-stick to casualty's finger as an added safety measure, reassess in 15 minutes, add second lozenge in other cheek as necessary to control severe pain, monitor for respiratory depression; IV or IO access obtained—morphine sulfate 5 mg IV/IO, reassess in 10 minutes, repeat dose every 10 minutes as necessary to control severe pain; monitor for respiratory depression; promethazine, 25 mg IV/IO/IM every 4 hours, for synergistic analgesic effect, and as a counter to potential nausea
11. Reassess fractures and recheck pulses
12. Antibiotics: recommended for all open combat wounds. If able to take po: moxifloxacin (400 mg po qd)
    If unable to take po (shock, unconscious, or penetrating torso injuries): cefotetan, 2 g IV (slow push over 3–5 minutes) or IM every 12 hours or ertapenam 1 g IV or IM every 24 hours
13. Pneumatic antishock garment may be useful for stabilizing pelvic fractures and controlling pelvic and abdominal bleeding. Their application and extended use must be carefully monitored. They are contraindicated for casualties with thoracic and brain injuries
14. Document clinical assessments, treatments rendered, and changes in casualty's status. Forward this information with the casualty to the next level of care

Phases of Care in TCCC

There has been general acceptance that trauma care on the battlefield must be appropriate to the tactical environment, especially with respect to potential contact with enemy forces and the presence of effective incoming hostile fire. In simplest terms, a medic caring for a casualty in the middle of an engagement with hostile forces needs to be much more selective about what interventions to perform than he would in a hospital emergency department. The primary focus should be on interventions that would address preventable causes of death on the battlefield until the tactical situation allows more comprehensive care. The integration of trauma care into the tactical flow that the unit must maintain in a casualty situation has been invaluable in training line commanders to structure their unit's response to casualty scenarios in a way that achieves the three guiding objectives of TCCC: (1) treat the casualty, (2) prevent additional casualties, and (3) complete the mission (Butler, 2001). Although dialogue is ongoing about the specifics of what of care to provide in the three phases of care (Care Under Fire, Tactical Field Care, and CASEVAC Care), authors discussing TCCC have not proposed changes to this phased approach to care (Butler and Hagmann, 2000; Butler, 2001; 2003; Tarpey, 2005; Butler et al., 2006; King et al., 2006; Mucciarone et al., 2006).

Tourniquets

Civilian trauma courses being used to train military combat medics in the early 1990s (Alexander and Proctor, 1993) strongly discouraged the use of tourniquets, and the view that tourniquets should only be used as a last resort to stop life-threatening bleeding is still held by some authors and trauma courses at the present (Welling et al., 2007). This aversion to the use of tourniquets to treat severe extremity hemorrhage denies the casualty treatment that is often lifesaving in the tactical environment.

A review of this topic for the original TCCC article found data from the Vietnam conflict that showed that the most common cause of preventable death on the battlefield was exsanguination from extremity wounds. Uncontrolled bleeding from extremity hemorrhage was the cause of death for >2,500 fatalities in Vietnam and is still the leading cause of preventable deaths on the battlefield today (Maughon, 1970; King et al., 2006; Starnes et al., 2006). The 1996 guidelines therefore advocated the aggressive use of tourniquets to control bleeding in the Care Under Fire phase of care (Butler et al., 1996) This was a restatement of calls for the judicious use of tourniquets from military authors in conflicts past (Wolff and Adins,1945).

In addition to the 2,500 Vietnam deaths noted above that could have been prevented with tourniquets, case series and reports describing lives saved or lost on the battlefield because of tourniquet issues date back at least as far as the Civil War, where Confederate General Albert Sydney Johnston was killed in the battle of Shiloh from a gunshot wound to the popliteal artery. He bled to death without thinking to use the tourniquet in his pocket (Welling et al., 2006).

The issue of which tourniquet to use has been addressed in recent studies. Testing in 2000 and 2001 was conducted on a tourniquet that was known as the "one- handed tourniquet" (Walters and Mabry, 2005), the name emphasizing the concern that a soldier with a traumatic amputation of one upper extremity would need to be able to apply the device with his single remaining hand. This tourniquet was found to be clearly more effective than the old strap and buckle device previously issued to combatants. A number of units (~20,000) were subsequently procured by the Army and fielded and a combat evaluation was undertaken. Although there was some positive feedback regarding the one-handed tourniquet, reports from combat medics who had used it indicated that it did not work well on lower extremity wounds. The U.S. Army Institute of Surgical Research (USAISR) subsequently performed a re-evaluation of commercially available tourniquets.

The USAISR tourniquet study noted that an ideal tourniquet for battlefield use should be light, durable, easily applied under combat conditions, and capable of reliable occlusion of arterial blood flow. Cost is also a factor. This study examined seven tourniquets available from commercial sources at the time and found that three were successful in completely occluding blood

flow in both upper and lower extremities: the Emergency Military Tourniquet (Delfi), the Combat Application Tourniquet (Phildurango LLC), and the Special Operations Force Tactical Tourniquet (Tactical Solutions LLC) (Walters et al., 2005b). The report from this study recommended that the Combat Application Tourniquet be carried by all combatants and that medics also carry the Emergency Medical Tourniquet (Walters et al., 2005b).

A laboratory evaluation of tourniquets for Canadian military forces examined five tourniquets (excluding the CAT tourniquet) and recommended the Emergency Military Tourniquet and latex surgical tubing as effective tourniquet choices (King et al., 2006). These authors also noted that ". . . tourniquet use in the tactical environment will continue to be an operational and medical requirement. All soldiers should be issued a tourniquet and trained in its use" (King et al., 2006).

The Navy Experimental Diving Unit published an evaluation on six tourniquets (excluding the Emergency Medical Tourniquet) in 2005 and noted that "all tourniquets except the OHT1 (One-Handed Tourniquet 1-inch width) and the Quick (Quickette) performed reasonably well on arms and legs, with median occlusion efficacies exceeding 70%." They also noted that: "The occlusion efficiacies of the CAT (Combat Application Tourniquet), the MAT (Mechanical Advantage Tourniquet), OHT2 (One-Handed Tourniquet 2-inch width), and TK (Tourni-Kwik) were statistically indistinguishable. These tourniquets also had low mechanical failure rates and clinically acceptable application times" (Ruterbusch et al., 2005).

All of the tourniquet studies noted above emphasized that appropriate training in tourniquet use on the battlefield is essential to their successful use. An excellent review of issues related to tourniquet use is provided by Walters and Mabry (2005).

The CAT was selected as the tourniquet of choice for deploying individuals and units by USSOCOM after the USAISR study noted above. This tourniquet was subsequently provided to deploying Special Operations (SOF) units (USSOCOM message 222016Z, March 2005). The CAT was also selected as the tourniquet of choice by the Army (Kiley, 2005a,b) and required by the U.S. Central Command for all combatants entering the CENTCOM area of operations (USCENTCOM message 061715Z, January 2005).

The two key questions to be answered with respect to tourniquets as we evaluate the success of this recommendation are: (1) can we document that these devices are saving lives on the battlefield and 2) what complications may be ensuing from their use? Dr. Carl Hughes, a prominent trauma surgeon in the Korean War, stated: "I had a number of vascular injuries sent to me with tourniquets applied. I believe that they were mainly the pneumatic tourniquets. I do not ever recall seeing limb loss as a result of a tourniquet. They were important, even life-saving in Korea" (Welling et al., 2006). Cloonan (2004) states that: "The current recommendations regarding the use of tourniquets in forward areas, which include liberal tourniquet use in active combat and later reassessment and replacement as time and circumstances permit, are surprisingly similar to those made after the Korean War."

A report describing the Israeli experience with tourniquets applied on the battlefield reported 91 uses on combat casualties (Lakstein, 2003). Seventy-eight percent of these tourniquets were successful in controlling bleeding. A higher percentage of success was reported for upper extremities (94%) than for lower extremities (71%). The authors also reported infrequent complications from tourniquet use, with seven instances of peripheral neuropathies attributed to tourniquet use in five casualties, for a rate of 5.5%. Both ischemia and mechanical pressure were postulated as etiologies for the neuropathies. No cases of ischemic limb necrosis were reported. The authors noted that an improvised "strap and windlass" type tourniquet was felt to be superior to the silicone variety that was issued. The authors described tourniquet use on the battlefield as fast, easy, and potentially lifesaving.

The TCCC Transition Initiative sponsored by USSOCOM and executed by the USAISR included training of SOF units in TCCC principles, fielding newly approved TCCC equipment to deploying SOF units, and providing a combat evaluation of this equipment through the collection of feedback from first responders and other medical providers (Butler and Holcomb, 2005; Butler et al., 2006). Data on the use of TCCC equipment and techniques have been compiled and include numerous reports of lifesaving tourniquet use by SOF combat medics and other first responders. One example of this type of report is the presentation by MSG Ted Westmoreland in which he reported the successful use of CATs to stop arterial bleeding of the left proximal thigh and another where this device was successful in controlling hemorrhage from a left lower leg wound (Butler et al., 2006). MSG Harold Montgomery reported seven Ranger lives saved with tourniquets in one operation (Butler et al., 2006). One report from the 31st Combat Support Hospital describing their experience for a 1-year period identified 44 casualties arriving at their facility for whom tourniquet use was judged to be lifesaving (Butler et al., 2006).

A total of 67 cases in which tourniquets were used successfully were identified. Since this collection did not necessarily include follow-through data from the casualty's entire hospitalization period, the incidence of peripheral neuropathies and other potential complications is not available from this report. Several combat medics initially reported problems controlling femoral bleeding with the CAT, specifically with the windlass breaking as it was tightened with the force necessary to be effective on the upper thigh (Butler et al., 2006; Appendix 5). The windlass on this device was subsequently strengthened by the manufacturer.

The Navy Operational Medical Lessons Learned Center database has several reports dealing with tourniquet use on the battlefield. One account describes two Marines successfully applying tourniquets to themselves while under fire in a HUMVEE (NOMLLC Lesson 40329), while another describes an Army Reservist embedded with a foreign unit who used a tourniquet to save the life of a casualty (NOMLLC Lesson 39582). The type of tourniquet in these two reports was not mentioned.

Tarpey (2005) addressed the use of tourniquets in his experience with the Third Infantry Division in Operation Iraqi Freedom (OIF): "Tourniquets played a decisive role in quickly and effectively stopping hemorrhage under fire and keeping a number of soldiers with serious extremity wounds involving arterial bleeding alive until they could eventually undergo emergent

surgery at the Forward Surgical Team." The author also stated that: "Given the intense conditions under which our medics treated casualties, it would have been absolutely impossible for them to have attempted to hold pressure over wounds while continuing to fight and treat other wounded." There were no known complications ensuing from tourniquet use in this report.

A recent retrospective analysis of the Navy SEAL casualties sustained in the Assault on Punta Patilla Airfield in Panama in 1989 found that control of extremity hemorrhage had the greatest positive impact on casualty care, noting that the three tourniquets applied in that action saved lives. No complications from tourniquet use were mentioned (Mucciarone et al., 2006).

Mabry (2001) described the injuries sustained in the Battle of Mogadishu in 1993 and reported that tourniquets were used liberally in the Combat Support Hospital and at least once on the battlefield in a casualty with a severe extremity wound. There were no reports of complications from tourniquet use in the casualties from this battle.

Starnes et al. (2006) note that "there is overwhelming evidence that the majority of survivable war injuries since the beginning of time have been predominantly extremity injuries." The authors call for the use of tourniquets in managing exsanguinating extremity hemorrhage, but note that an improperly applied tourniquet can actually increase blood loss if it is tight enough to impede venous return, but loose enough to allow arterial flow.

Another approach to addressing metrics for tourniquet use is the study performed jointly by USSOCOM, USAISR, and the Armed Forces Institute of Pathology (Holcomb et al., 2007a) This project was a postmortem analysis of the first 82 fatalities suffered by Special Operations forces in the Global War on Terrorism (GWOT). Seventy of the 82 deaths examined were judged to be nonpreventable, while 12 of the fatalities were judged to have wounds that were potentially survivable. Three of these deaths were attributable to failure to apply an effective tourniquet to extremity wounds. Other reports of fatalities that might have been prevented by prompt application of an effective tourniquet have been noted during OIF/Operation Enduring Freedom (West et al., 2004; Butler et al., 2006).

Tourniquet use in the tactical prehospital environment was reviewed by Holcomb in the 2004 Fitts Lecture to the American Association for Surgical Trauma and summarized in the following statement: "Hemorrhage control with liberal tourniquet use and advanced hemostatic dressings is paramount" (Holcomb, 2005a).

A final note on tourniquet use is that battlefield experience has shown that tourniquets are not intuitive devices and that combatants must be well trained in their use. Mistakes in tourniquet use reported from combat units include using tourniquets on wounds in which severe bleeding was not present, not using them on other wounds where they were indicated, loosening the tourniquet to allow intermittent return of blood flow to the injured extremity, not applying the tourniquet tightly enough, and removing the tourniquet prematurely (Butler et al., 2006). Clearly presented guidelines on tourniquet application and removal reflecting the current U.S. Army guidelines on this issue are available in the TCCC section of the *PHTLS Manual* (McSwain and Salome, 2006). Additional thoughts on tourniquet guidelines are available from other authors as well (Navein et al., 2003).

Hemostatic Agents

No hemostatic agents had been approved by the Food and Drug Administration (FDA) and proven to be effective in stopping life-threatening hemorrhage at the time of the publication of the original TCCC guidelines; therefore, these agents were not addressed at that time. By the 2003 revision, however, a number of candidate hemostatic agents to aid in the control of battlefield bleeding had been developed. The agents best supported by data from ongoing studies at the time (Alam et al., 2003, 2004; Sondeen et al., 2003b; Pusateri et al., 2003, 2004) as being able to stop massive hemorrhage were reviewed by the committee. Both the chitosan-based bandage HemCon (HemCon Medical Technologies, Portland, Oregon) and the zeolite powder QuikClot (Z-Medica, Wallingford, Connecticut) were judged to be effective based on study findings to date. Although the committee was not able to identify a clear winner based on efficacy, there were concerns about burns from the exothermic reaction produced by QuikClot (Burris, 2003; Pusateri et al., 2004; Wright et al., 2004a,b) and HemCon was selected as the initial TCCC hemostatic agent of choice (McSwain et al., 2003) (Table IV).

A re-evaluation of the hemostatic agent recommendation was conducted by the CoTCCC for the 2006 TCCC guidelines. A focused meeting of the CoTCCC was conducted on this topic. Combat-experienced first responders and trauma surgeons were asked to describe their experiences with both QuikClot and HemCon. The Army and Special Operations forces had been issuing and using HemCon while the Marine Corps and Air Force had elected to use QuikClot. The findings from Wedmore and his colleagues noted below were presented, as were case reports from the TCCC Transition Initiative (Butler et al., 2006). Published accounts of Quikclot use on the battlefield were not available at the time of this review, although it had been reported successful in one trauma surgery patient in whom other attempts at operative hemostasis had failed (Wright et al., 2004a,b). Several Navy corpsmen assigned to the Marine Corps described successful uses of QuikClot on the battlefield. Although there were reports of pain on application from use of QuikClot, there were also anecdotal reports of lives saved by use of this agent. Trauma surgeons caring for USMC casualties reported that tissue damage from QuikClot's exothermic reaction, while observed in the operating room, had not presented major problems nor had it resulted in significant additional tissue loss in the casualties in whom it had been used. Both agents have been shown to be effective in animal models of severe bleeding (Alam et al., 2003, 2004, 2005; Pusateri et al., 2003; Sondeen et al., 2003b; Ahuja et al, 2006). It was the finding of the committee that, once again, a clear winner in terms of efficacy was not evident. The revised position published in the 2006 guidelines (Table V) was that both agents should be carried by all combatants on the battlefield. HemCon was recommended for use in the Care Under Fire Phase for cases of severe external bleeding not amenable to tourniquet placement. Both agents were recommended for use in the Tactical Field Care and CASEVAC phases of care, with QuikClot to be used as

a secondary agent if HemCon had not been effective or was not available (McSwain and Salome, 2006). This position was reiterated by a recently published review article on hemostatics (Pusateri et al., 2006).

HemCon has since been reported to be effective on the battlefield in a retrospective study of its use by Special Operations forces (Wedmore et al., 2006a,b). The authors reported 64 uses of HemCon in combat casualties. In 97% of the casualties, HemCon use resulted in cessation of bleeding or improvement in hemostasis. The majority (66%) of these uses followed treatment failures with standard gauze dressings. Use of HemCon was most important in the treatment of superficial torso, head and neck, and very proximal limb injuries in which a tourniquet could not be applied.

Tarpey (2005) reported a case of QuikClot use in OIF on a thigh wound with femoral bleeding in which the medic was unable to stop the bleeding with a tourniquet. QuikClot was poured carefully onto the wound and successfully stopped the bleeding without causing skin burns. A case series of QuikClot use has recently been prepared (Rhee et al., in press). There were 83 external uses of this agent by first responders in the field and all were reported to be successful at controlling the hemorrhage. The exothermic reaction produced by QuikClot produced pain that ranged from mild to severe in this series. There were three reported cases of skin burns, with one burn requiring skin grafting (Rhee et al., in press). In contrast, a Marine Corps battalion surgeon submitted a case series to the Navy Operational Medical Lessons Learned Center in which QuikClot was unsuccessful in four battlefield uses, with two of the four casualties exsanguinating (NOMLLC Lesson Learned 8177). It is not clear from this report that direct pressure was used in conjunction with the QuikClot application as the directions call for; therefore, these failures may have been at least in part a training issue. Another recent report has described a series of four casualties with cutaneous burns from QuikClot use (McManus et al., 2007).The reports of pain and cutaneous burns from QuikClot use strengthen the case for using QuikClot only when HemCon has failed or is not available.

The fibrin dressing has also shown promise (Sondeen et al., 2003a,b; Kheirabadi et al., 2005, 2007; Acheson et al., 2005) but is expensive (~$1,000 per dressing) and is not FDA approved at present (Pusateri et al., 2006).

Nasopharyngeal Airway

The preeminence of opening the airway has been well reinforced by cardiac and trauma courses that emphasize the "ABCs"—airway, breathing, and circulation. Definitive airway control for an unconscious patient in the civilian sector is generally considered to be endotracheal intubation.

An analysis of combat fatalities in Vietnam, however, showed that only a very small percentage of deaths in combat casualties were due to airway compromise (McPherson et al., 2006). Furthermore, measures that are well known to be successful in the civilian sector such as manually positioning the head to open the airway or performing endotracheal intubation may not have the same efficacy on the battlefield, where most of the airway deaths are due to maxillofacial trauma. Blood in the airway and anatomy distorted by trauma may make intubation exceedingly difficult to perform in the combat prehospital environment. Additionally, intubation is not a skill frequently practiced by most combat medics and the white laryngoscope light that is displayed during the procedure is not recommended for nighttime combat operations.

Most unconsciousness on the battlefield in classic ground combat results from hemorrhagic shock or penetrating trauma to the head. For these casualties, the 1996 TCCC guidelines called for the use of a nasopharyngeal airway as the airway device of choice when the casualty did not have injuries that would preclude the effective use of this device. This recommendation has also been included in the 2003 and 2006 guidelines.

Several battlefield reports have addressed this issue. One is an account of an Israeli physician who attempted to intubate an unconscious casualty on a battlefield at night. The physician was shot in the head and killed during the intubation attempt while the laryngoscope light was being displayed (unpublished data).

Another is a report of the intracranial insertion of a nasopharyngeal airway in a patient with a closed head injury (Martin et al., 2004). Use of this airway in casualties with closed head injuries may need to be re-evaluated, although adequate training in the insertion of this device, with an emphasis on the direction of insertion being 90 degrees to the perpendicular plane of the face rather than in a cephalad course along the long axis of the nose, should prevent this complication.

One concern about the use of a nasopharyngeal airway is the potential for an unconscious casualty to vomit and aspirate. There were no reports identified in Iraq or Afghanistan in which this occurred despite the potential risk. This potential risk must also be considered in light of the potential risk of a preventable death should an esophageal intubation not be recognized in the confusion of a combat casualty scenario.

Surgical Airways

The 1996 TCCC guidelines called for the aggressive use of surgical airways in the Tactical Field Care phase when maxillofacial trauma makes the use of a nasopharyngeal airway inadequate to open the airway. This recommendation has been carried forward into the 2003 and 2006 guidelines.

One Army Special Operations unit described a series of prehospital surgical airways. There were seven procedures done over the course of several years. Four of the procedures were done for maxillofacial trauma, two for unconsciousness (and presumably failure of less invasive measures to restore the airway), and one for seizures. Six of the seven procedures were accomplished successfully with five of the seven casualties surviving. The remaining casualty was successfully intubated after the unsuccessful attempt at a surgical airway. Neither of the two casualties who died did so as a result of airway compromise (Butler et al., 2006).

The study by Holcomb et al. (in press; a) on Special Operations fatalities in the GWOT noted that 1 of the 12 potentially preventable deaths was due to airway failure after maxillofacial trauma from a gunshot wound. The attempted intubation was unsuccessful and no surgical airway was attempted.

Tension Pneumothorax

Tension pneumothorax can be fatal if not treated promptly and in previous conflicts has been a leading cause of prevent-

able death in combat casualties (Maughon; 1970; McPherson et al., 2006). On the battlefield, the usual clinical indicators of decreased breath sounds, tracheal shift, and hyperresonance to percussion may be difficult to appreciate (Butler et al., 1996). Accordingly, the 1996 TCCC guidelines called for aggressive presumptive diagnosis and treatment for suspected tension pneumothorax in the prehospital combat environment: "Consider tension pneumothorax and decompress if a casualty has unilateral penetrating chest trauma and progressive respiratory distress." The 2003 and 2006 guidelines modified this slightly to include blunt torso trauma and respiratory distress even if it not progressive as part of the indication for needle thoracostomy: "Consider tension pneumothorax and decompress with needle thoracostomy if a casualty has torso trauma and respiratory distress" (McSwain et al., 2003; McSwain, 2006) (Table V).

Chest tubes are not recommended in this phase of care because: (1) they are not needed to provide initial treatment for a tension pneumothorax; 2) they are more difficult and time-consuming for relatively inexperienced medical personnel to perform, especially in the austere battlefield environment; and 3) chest tube insertion is probably more likely to cause additional tissue damage and subsequent infection than needle thoracostomy (Butler et al., 1996). In a study by Holcomb et al. (in press; b), needle thoracostomy using a 14-gauge needle or Cook catheter was just as successful as tube thoracostomy for relieving tension hemopneumothorax.

The potential for serious complications from needle thoracostomy exists (Butler et al., 2003). Some authors have suggested that needle thoracostomy may not be indicated in civilian prehospital trauma patients because it is often ineffective and may be overused (Cullinane et al., 2001). Other authors disagree, emphasizing that there is evidence that it can be done successfully with low complication rates (Barton et al., 1995; Eckstein and Suyehara, 1998; Heng et al., 2004; Davis et al., 2005; Massarutti et al., 2006). One study of 55 patients found a significant improvement in oxygen saturation with no major complications and no recurrence of tension pneumothorax (Massarutti et al., 2006).

Although there are fewer chest wounds in U.S. casualties now that body armor is routinely worn (Mabry, 2000), the ability to manage tension pneumothorax remains a skill of great importance to the combat medic. There are still wounds to the torso from shrapnel fragments and bullets entering either laterally, between the ceramic plates of the body armor, or from above or below the protected areas. Additionally, medics and corpsmen may be called upon to treat both civilian casualties and wounded prisoners of war who did not have the protection of body armor. Needle thoracostomy is also needed for those instances where tension pneumothorax occurs in noncombat settings (Brimms, 2004; Vinson, 2004). Longer delays to definitive care, the potential for worsening of tension pneumothorax in aeromedical transport as ambient pressure is lowered, and the potentially deleterious effects of hypobaric hypoxia in operations at altitude all strengthen the case for this skill to be retained by combat medics.

McPherson et al. (2006) recently published a retrospective analysis of tension pneumothorax from the analysis of U.S. fatalities in Vietnam and reported that this injury was the cause of death in 3 to 4% of fatally wounded combat casualties in that conflict, making it the second leading cause of preventable death (behind exsanguination from extremity injuries) on the battlefield.

There have been at least two instances of suspected tension pneumothorax in U.S. casualties reported in the GWOT to date. Westmoreland described the successful needle decompression of a suspected tension pneumothorax in OIF using a 14-gauge, 3.5-inch needle (Butler et al., 2006; Appendix 7). Another case report by a former Navy SEAL corpsman documented the successful decompression of a tension pneumothorax suffered by a Marine officer during OIF (NOMLLC Lesson Learned 41655).

Holcomb et al.'s (2007a) retrospective analysis of the first 82 Special Operations fatalities in the GWOT found that one SOF operator made a fast-rope insertion, which resulted in a 25-foot fall onto rocky mountainous terrain. The fall caused a closed head injury and bleeding from multiple thoracic, intra-abdominal, and retroperitoneal sites. The bleeding sites were felt to have been relatively minor and probably not requiring surgical intervention. This individual was also found to have a tension pneumothorax. The time from injury to death for this casualty was 4.5 hours. This casualty might possibly have been saved had a needle thoracostomy been performed by a medic in the field, although it cannot be said with certainty that the individual would not have died from the closed head injury alone.

The questions at hand when discussing needle thoracostomy on the battlefield are less "should it be done?" than: (1) who should be trained to do the procedure?—just combat medics or should nonmedical combatants be taught this skill as well; (2) patient selection—what are the best clinical indicators for deciding who should be treated for a tension pneumothorax on the battlefield; (3) technique—should the second intercostal space in the mid-clavicular line remain the preferred location or should the lateral approach be used as suggested by Heng et al.(2004); (4) how best to train for this procedure; and (5) length and gauge of needle to be used.

Previous recommendations were for a cannula 3- to 6-cm long for needle thoracostomy. Chest wall thickness in the second intercostal space in the mid-clavicular line was found to range from 1.3 to 5.2 cm in 54 patients. The authors recommended that the shortest cannula length used for this procedure be 4.5 cm and that an unsuccessful attempt at needle thoracostomy be followed by attempt with a longer cannula or chest tube (Britten and Palmer, 1996; Britten et al., 1996). Another study found a mean chest wall thickness of 4.24 cm and noted that a catheter length of 5 cm would reliably penetrate the pleural space of only 75% of patients (Givens et al., 2004). Westmoreland reported success with a 14-gauge, 3.25-inch needle in treating tension pneumothorax in a casualty scenario in Afghanistan (Butler et al., 2006).

The U.S. Army recognized the need to have some individuals who are not medics be trained in additional skills beyond those that every combatant should possess. This Combat Lifesaver Program has recently been adopted by the Marine Corps as well. Needle thoracostomy is one of four skills (the others being starting an intravenous line, performing fluid resuscitation when indicated, and traction splinting) that are recommended by the TCCC guidelines to be taught to Combat Lifesavers, but not to all combatants. Deciding what percentage of individuals in a unit should be trained to this higher skill level is not addressed

by the *PHTLS Manual*, but is left up to the military organizations considering this decision (McSwain and Salome, 2006).

Intravenously Access and Intraosseous Infusion Devices

TCCC recommends a more conservative approach to establishing prehospital intravenous (IV) access than civilian practice, recommending this intervention during the Care Under Fire and Tactical Field Care phases only when fluid resuscitation is indicated or if IV medications are required. There are several reasons not to start an IV if there is not a good indication: (1) starting an IV takes time and may interfere with the unit's tactical flow or with the medic's ability to treat other casualties and (2) using IV fluids for individuals who do not need them makes them unavailable for subsequent casualties who may need them badly. In the words of a Special Forces medic: "Don't waste time on lines to conscious wounded with stable BPs" (Butler et al., 2006; Appendix 9). Conservation of IV fluids is also a reason for the recommendation to start a saline lock if it is believed that IV access is warranted. Two other points in favor of saline locks versus routine initiation of IV fluids are the increased ease of moving casualties when one is not required to manage IV bags and lines and the reduced risk of traumatic IV disinsertion as a result of the IV line snagging on something during patient movement. These innovations have been well received by the combat medic community and are now in common practice.

Fluid resuscitation for hemorrhagic shock is a clear indication for IV access on the battlefield, but the peripheral vasoconstriction that accompanies shock makes IV access more difficult. Previously used measures such as venous cutdown procedures are time-consuming and not well suited for the battlefield. Intraosseous (IO) infusion devices provide quick, reliable intravascular access when peripheral IVs cannot be started (Dubick and Holcomb, 2000; LaRocco and Wang, 2003; Johnson et al., 2005; Isbye and Nielson, 2006). In a study published in 2000, the Pyng *FAST-1* (Pyng Medical Corp., Richmond, BC, Canada) was given the best rating by the Special Operations combat medics and corpsmen who participated in the trials (Calkins et al., 2000). The 2003 TCCC guidelines added the recommendation for combat medics to carry and be trained in the use of IO infusion devices. After a review of the available IO devices, the CoTCCC concluded that the Pyng *FAST-1* is the IO device best suited for trauma care on the battlefield (McSwain et al., 2003; McSwain and Salome, 2006).

IO devices have proven successful in combat based on input from combat medics (Butler et al., 2006). There were four successful uses of the *FAST-1* in casualties reported by three providers in a recent military medical lessons learned forum (Jarvis et al., 2007). IO access has also been found to be a very successful adjunct in establishing IV access in simulated chemical warfare casualty scenarios (Ben-Abraham et al., 2003; Vardi et al., 2004). In one first responder opinion favoring a device other than the Pyng *FAST-1*, Briggs stated that: "The Bone Injection Gun has been more user friendly than the FAST-1 and is easier to remove" (Butler et al., 2006; Appendix 9). Another report on the prehospital use of IO devices in civilian settings highlights the need for adequate training before using them in the field (Miller et al., 2005).

Practical experience with these devices has emphasized the need to use a syringe to eject the plug present in the lumen of the device after insertion. Use of human volunteers to conduct practice insertions of the device is not recommended for training in this device (Brown, 2005a).

Fluid Resuscitation

The 1996 TCCC guidelines suggested a somewhat different approach to IV fluid resuscitation in tactical settings than was practiced at the time in the civilian sector. Giving a fluid bolus to individuals who are not in shock is not necessarily helpful to the casualty and may be harmful if it delays treatment of other serious injuries, causes a delay in the unit's tactical flow, or causes fluids to not be available to individuals who truly need fluid resuscitation. The most clear-cut indication for fluid resuscitation in the field is severe hemorrhage that has been controlled, but which resulted in shock before hemostasis was established (Butler et al., 1996). For individuals with uncontrolled hemorrhage, the best available data at the time found that prehospital fluid resuscitation increased the mortality rate for individuals with penetrating torso trauma and shock when compared with fluid resuscitation that was postponed until the time of operative intervention (Bickell et al, 1994).

For individuals requiring fluid resuscitation in the prehospital setting, hetastarch was recommended over crystalloid solution because of its much longer intravascular presence after administration, preventing both extravascular fluid overload and the need for additional fluid administration in cases of delayed evacuation (Butler et al., 1996).

The USSOCOM-sponsored workshop on the "Management of Urban Warfare Casualties" in 1998 produced the first change to these recommendations. Despite the results of Bickell's study noted above, a consensus of the trauma experts present believed that fluid resuscitation is indicated for individuals who are unconscious or who have altered mental status as a result of hypovolemic shock. The opinion of the panelists was unanimous on this point and was echoed by a conference on this topic jointly sponsored by the U.S. Army Medical Research and Materiel Command and the Office of Naval Research (Holcomb, 2003). This conference produced the hypotensive resuscitation strategy for individuals with decreased state of consciousness or unconsciousness recommended in the 2003 and 2006 TCCC guidelines. Hextend (Hospira, Inc, Lake Forest, Illinois) is recommended instead of the previously recommended Hespan (B. Brau Medical, Irvine, California) because of a possible decreased incidence of coagulopathy with the former fluid (Holcomb, 2003; McSwain et al., 2003). The current recommendation for casualties in shock during Tactical Field Care is an initial infusion of 500 cc of Hextend, followed by 30 minutes of observation. If unsatisfactory clinical improvement is noted, an additional 500 cc of Hextend is given.

The rationale for this hypotensive resuscitation strategy using Hextend as the resuscitation fluid has been reviewed several times in recent years and found to be sound from the research literature (Holcomb, 2005a; Donham and Otten, 2006) .In recent studies with animal models of severe hemorrhage in which definitive repair of the injury has not been accomplished, hypotensive resuscitation is more effective than normotensive resuscitation in maintaining hemostasis (Sondeen et al., 2003a; Han-

drigan et al., 2005). The premise that resuscitation with Hextend provides better sustained effect with smaller fluid volume than crystalloid has also been confirmed in animal models (Handrigan et al., 2005).

Another innovation produced by the 2003 guidelines was the allowing of oral fluids in individuals who were able to take them. Trauma surgeons on the committee pointed out that dehydration was a common and significant problem in the care of combat casualties and recommended this change (McSwain and Salome, 2006).

The 2006 guidelines also included a caveat to the hypotensive resuscitation strategy mentioned previously that calls for more aggressive fluid resuscitation in individuals with traumatic brain injury (TBI) and decreased radial pulse, reflecting the need to maintain cerebral perfusion in individuals who may have increased intracranial pressure (Table V).

Tarpey (2005) reported his OIF experience with hypotensive resuscitation using Hespan. His account reads: "We adhered throughout to the principle of hypotensive resuscitation, using IV fluids only when appropriate. Casualties not in shock were encouraged to take fluids orally. Those casualties in shock received 1,000 cc of Hespan, the colloid available to us. It was very effective in resuscitating casualties without complications noted. Given our low supplies and little room to transport everything throughout the length of Iraq, we found colloids to be the better choice of fluid for resuscitation" (Tarpey, 2005). Westmoreland reported success on the battlefield with hypotensive resuscitation as well: "Works well in combat—7 of 8 U.S. critical survived 5+ hours on the ground and 3 to 4 hours for CASEVAC. Titration to mentation seemed to work well in most cases" (Butler et al., 2006).

Battlefield Antibiotics

The use of antibiotic prophylaxis in patients with significant trauma and open wounds is routine in the hospital setting. Early administration is preferred over delayed use. In the tactical prehospital setting, transport to the hospital may be delayed for many hours (Bowden, 1999; Naylor, 2005.) The use of cefoxitin was recommended in the initial TCCC guidelines. This agent has the advantage of providing broad-spectrum coverage, being relatively inexpensive, and the ability to be given IV or intramuscular (IM) (Butler and Smith, 1996; Butler et al., 1996).

The 2003 guidelines included a recommendation that oral antibiotics be used in casualties for whom this is feasible (O'Connor and Butler, 2003). Oral antibiotics do not require mixing and IV/IM administration by the medic, thus decreasing both administration time and load carriage requirements on the medic. The fourth-generation fluoroquinolones are broad-spectrum agents with excellent bioavailability when taken by mouth. Gatifloxacin and moxifloxacin were found to be similar in efficacy in a literature review and the former medication was recommended based on pricing at the time (O'Connor and Butler, 2003). Additionally, for casualties unable to take medications by mouth, cefotetan was recommended as a longer-acting alternative to cefoxitin with similar spectrum and cost (O'Connor and Butler, 2003).

In the interim between the 2003 and 2006 guidelines, cefotetan became difficult to procure for carriage by medics. A search for a suitable alternative produced a recommendation to use ertapenam instead (McSwain and Salome, 2006). Also in this interim, significant dysglycemic side effects began to be reported with gatifloxacin and this medication was withdrawn from the market. Moxifloxacin was selected as a suitable alternative for a broad-spectrum oral antibiotic (McSwain and Salome, 2006). The search for the ideal antibiotic will continue, with some authors recommending limited-spectrum antibiotics based on the bacteriology of wounds on presentation (Murray et al., 2006) and others advocating a more broad-spectrum choice (Hell, 1991; O'Connor and Butler, 2003; Kucisek-Tepes et al., 2006).

The use of prophylactic antibiotics is recommended as part of the hospital management of war wounds (Burris et al., 2004; Mazurek and Ficke, 2006; Starnes et al., 2006). Antibiotics must be given early after the injury to be effective (Mellor et al., 1996). In military operations, evacuation is often delayed, and if antibiotics are to be successful, they must be administered by the medics. The consequences of not doing so are reflected in the relatively high rate of wound infections reported by Mabry et al. (2000) in Mogadishu (16 of 58 casualties wounded in action [WIA]), where the evacuation of most of the casualties was delayed for ~15 hours and antibiotics were not administered by the medics. The authors of that article called for antibiotics to be administered by combat medics in the field.

Tarpey (2005) reported his experience with antibiotics given in the prehospital setting in OIF. In contrast with the experience in Mogadishu, all of Tarpey's OIF casualties (32) with open wounds received antibiotics in the field and none of them developed wound infections. They chose their antibiotics based on the TCCC recommendations as modified by medication availability, using levofloxacin for an oral antibiotic, IV cefazolin for extremity injuries, and IV ceftriaxone for abdominal injuries.

MSG Ted Westmoreland described the results of battlefield antibiotic use in one casualty scenario involving 19 Ranger and Special Forces WIA as well as 30 Iraqi WIA and reported a "negligible" incidence of wound infections in this group (Butler et al., 2006).

A search of the NOMLLC Lessons Learned revealed no entries describing first responder experiences with the use of battlefield antibiotics.

Battlefield Analgesia

The initial recommendations in the TCCC guidelines on battlefield analgesia called for the use of IV rather than IM morphine because of the more rapid onset of action and increased ease of titration (Butler and Smith, 1996; Butler et al., 1996). The 2003 recommendations maintained this recommendation and added the oral, nonopiate analgesic Vioxx as an option for less severe pain. Vioxx, a cyclooxygenase 2 inhibitor, was chosen over other nonsteroidals primarily because it did not interfere with platelet function, as aspirin and cyclooxygenase 1 nonsteroidal anti-inflammatory drugs do (McSwain et al., 2003). This medication was subsequently withdrawn from the market because of cardiovascular problems associated with long-term use. The 2006 guidelines therefore substituted meloxicam and added extended-release acetaminophen for oral analgesia for those individuals in a combat setting with relatively minor wounds who can continue to perform effectively in their unit as long as they are not given narcotics for analgesia. Use of opiate

analgesia in these individuals is undesirable, in that they may be rendered non-battleworthy by their treatment when they were not incapacitated by the wounds (McSwain and Salome, 2006).

Another addition to battlefield analgesia in the 2006 guidelines was oral transmucosal fentanyl citrate (OTFC). The successful use of this medication in OIF combat operations was first described in Army Rangers in 2004 (Kotwal et al., 2004). Fentanyl lozenges were used in 22 hemodynamically stable trauma patients who had no other indications for an IV other than pain management. OTFC at a dose of 1,600 μg was found to be successful in relieving pain and to have a sustained effect up to 5 hours after dosing. There was one episode of hypoventilation requiring treatment with naloxone that led the authors to recommend that future use entail lower dosing of OTFC with additional titration as required. The current TCCC guidelines call for an initial dose of 800 μg of OTFC, with an additional dose in 15 minutes if required. A recent review of pain management in austere environments stated that: "Overall OTFC appears to be ideal for administering safe, rapid-onset oral opiate analgesia in the prehospital austere setting" (Wedmore et al., 2006a,b).

Oxygen Administration and Patient Monitoring on the Battlefield

Oxygen is routinely administered to patients with significant trauma in the civilian prehospital setting. It is much less available on the battlefield, especially in the phases of care before CASEVAC care. The 1996 guidelines called for oxygen to be administered to seriously injured patients during CASEVAC (Butler and Smith, 1996; Butler et al., 1996).

TCCC guidelines are now more precise in this area and state that most casualties do not require oxygen during CASEVAC, but that supplemental oxygen should be administered for the following indications (Grissom et al., 2006; McSwain and Salome, 2006): low oxygen saturation by pulse oximetry; injuries associated with impaired oxygenation; unconscious casualties; TBI patients (maintain oxygen saturation >90); casualties in shock; and casualties at altitude.

A review of the literature from Iraq and Afghanistan found no reports that provide specific evidence relating to the effect of these recommendations on casualty survival, but the study by Grissom et al. (2006) noted that the above provides a solid foundation on which to base this guideline.

The routine carriage of pulse oximeters by combat medics is now recommended and provides a ready way to determine oxygen saturation. Pulse oximetry has been found to be an excellent tool for medics in the field in that they can monitor oxygen desaturation and determine whether or not a lifesaving intervention such as a surgical airway or needle thoracostomy is indicated. It will also monitor the effects of these interventions. Westmoreland described a multiple casualty scenario in Afghanistan in which he states that "pulse oximetry was key in rapid/constant triage" (Butler et al., 2006).

Blood Products on the Battlefield

The use of blood products in the prehospital setting was not addressed in the original TCCC article. The 2003 guidelines recommended that packed red blood cells be available on CASEVAC platforms when logistically feasible. This recommendation has been carried forward into the 2006 guidelines with more specific guidance on when to use type O PRBCs and how much to administer. There has been at least one report of the use of blood products (PRBCs) in the CASEVAC phase of care (West et al. 2004). The author of that article makes the point that only 1 unit was transfused and that this single unit may not have been lifesaving, but it demonstrates the feasibility of carrying and administering PRBCs on CASEVAC platforms. The practice of battlefield transfusions from soldier-to-soldier is still seen occasionally, but this has been discouraged in the guidelines because of the time and logistics involved on the battlefield, concerns about ensuring donor compatibility, and the fact that this procedure leaves the donor(s) hypovolemic after the procedure in a tactical environment where they could be the next person(s) shot.

Hypothermia on the Battlefield

The first two sets of TCCC guidelines contained no mention of the management of hypothermia on the battlefield. The hypovolemic shock seen in trauma patients, however, both predisposes the casualty to hypothermia and is potentially worsened by the coagulopathy that ensues from hypothermia (Fries et al. 2002; Carr, 2004; Eastridge et al., 2006). Hypothermia-induced coagulopathy is well described and results from decreases in platelet function (Watts et al., 1998; Peng and Bongard, 1999;Wolberg et al., 2004), coagulation cascade enzyme activity slowing (Watts et al., 1998; Peng and Bongard, 1999), and alterations of the fibrinolytic system (Peng and Bongard, 1999). Hypothermia is a problem even in relatively warm climates, because the presence of hypovolemia causes decreased ability to produce heat and to maintain normal body temperature. This problem is exacerbated by aircraft-based CASEVAC, where the casualty is exposed to cooler temperatures and significant wind chill at altitude during a rotary-wing evacuation in an open-cabin airframe. Hypothermia has been found in recent years to be more prevalent than generally realized and was found to independently contribute to overall mortality (Arthurs et al., 2006). The importance of instituting aggressive steps to prevent hypothermia in the field has been emphasized (Peng and Bongard, 1999; Husum et al., 2002), and simple interventions have been demonstrated to be effective in decreasing the incidence of hypothermia in prehospital settings with prolonged evacuation (Husum et al., 2002). A number of specific interventions have been recommended in the 2006 TCCC guidelines to prevent hypothermia in combat casualties (McSwain and Salome, 2006). These interventions reflect the guidance on this topic provided by the Assistant Secretary of Defense for Health Affairs (Winkenwerder, 2006). These measures have only recently been put into place and no metrics are available at this point in time to document their efficacy in the current conflict. The article by Arthurs et al. (2006), however, clearly shows that hypothermia is an independent predictor of mortality in combat casualties in OIF.

Combining Good Medicine with Good Tactics

One of the most difficult aspects of TCCC to quantify and yet one of the most important to capture has been the impact of the integration of tactically appropriate trauma care into the unit's tactical flow during combat.

One of the best illustrations of this principal is the description of the remarkably successful Israeli raid on the Entebbe airport, where a number of hostages were rescued (McRaven, 1996). The rescue force landed on the darkened airfield at Entebbe and conducted a successful approach to the terminal where the hostages were being held. At the onset of the assault phase of the operation, however, the commander of the assault force sustained a gunshot wound to the chest. Rather than stopping the operation and focusing on the medical care of the commander, however, the assault force continued the tactical flow of the assault. The rapid-sequence rescue resulted in the successful rescue of all hostages with no loss of hostage lives. The assault took less than 2 minutes, after which the assaulters were then able to care for the commander after the terminal had been secured. A stark contrast to this operation was the rescue attempt on May 4, 1974, in the Israeli village of Ma'alot, in which the assault phase of the operation was not successful in killing the 3 terrorists involved before they opened fire on their 105 hostages, resulting in 22 killed and 56 wounded; most of the victims were school children (McRaven, 1996).

Another compelling look at a real-world casualty scenario is described by Naylor (2005) in his account of Operation Anaconda in Afghanistan and, in particular, the action on Takur Ghar (Roberts Ridge) in which a helicopter full of Rangers was sent to provide reinforcement to a Navy SEAL element in contact with Al-Quaida fighters. The helicopter was hit by rocket fire as it landed and then came under heavy small-arms fire. There were multiple casualties to be cared for, but the intense, ongoing tactical situation dictated that only that care absolutely necessary to save lives be rendered while the engagement was ongoing.

The actions described above illustrate the high cost of failure to give the tactical situation the appropriate priority when a combat unit takes casualties. More casualties, captures, or deaths among unit members may result if casualty care takes inappropriate precedence over tactical considerations before the engagement is concluded. For this reason, the appropriate care while under fire that achieves both the best long-term result for those already wounded as well as preventing further injury to other team members is often stated as "accurate return fire."

Comprehensive Metrics

The discussion in this article to this point has presented reports of the experience to date of individual elements of care recommended by the TCCC guidelines. This section will examine the larger-scale metrics currently available for TCCC.

One important metric is an expanding scope of users. At the time of this writing, TCCC is used by all of the conventional forces in the U.S. military as well as by Special Operations forces (Allen et al., 1999; Brown, 2005c; Hostage, 2005; Holcomb, 2005a; Kiley, 2005a,b; BUMED message 111622Z, 2006 December 2006; USCG message 221752Z November 2006; USMC message 020004Z August 2006).

Holcomb (2005a) noted that TCCC was initially used only by Special Operations forces, but because of its straightforward instructions and applicability, it is now used by most conventional forces. It is currently the standard for medic training in the U.S. armed services.

This general acceptance of the principles of TCCC has come about as positive reports concerning the efficacy of TCCC have come in from GWOT battlefields. Eastridge et al. (2006), in their discussion of the newly developed Theater Trauma System state: "Other courses such as Tactical Combat Casualty Care, Emergency War Surgery, and the Joint Forces Combat Trauma Management Course, have revolutionized the way medical providers are trained for wartime deployment."

Published observations of individuals or units who have used the TCCC guidelines in combat have become available. Tarpey (2005) described the use of TCCC by elements of the Third Infantry Division: "The adoption and implementation of the principles of TCCC by the medical platoon of TF 1-15 IN in OIF 1 resulted in overwhelming success. Over 25 days of continuous combat with 32 friendly casualties, many of them serious, we had 0 KIA and 0 Died of Wounds, while simultaneously caring for a significant number of Iraqi civilian and military casualties."

The 101st Airborne Division stated that "by teaching and using (TCCC) ideas, the 101st has achieved one of the highest casualty survival rates in combat of any unit in the Army" (Gresham, 2005).

An article in *Tip of the Spear*, the official publication of the U.S. Special Operations Command, stated that: "Multiple reports from SOF First Responders have credited TCCC techniques and equipment with saving lives on the battlefield" (Bottoms, 2006). The Commander of the U.S. Special Operations Command sent a letter of appreciation to the Army Surgeon General for the outstanding work done by the USAISR in establishing a pilot program to fast-track new TCCC training and equipment to deploying SOF units and then collect data about the success of these measures. This letter stated that these efforts had ". . . produced remarkable advances in our force's ability to successfully manage battlefield trauma" (Brown, 2005b).

A team from Madigan Army Medical Center used TCCC-based training to prepare 1,317 combat medics for deployment to Iraq or Afghanistan. Of the 140 medics who subsequently deployed to Iraq for 1 year, "99% indicated that the principles taught in the TCCC course helped with the management of injured casualties during their deployment" (Sohn et al., 2006).

In a presentation to the Special Operations Medical Association in December 2005, a senior enlisted medic in an Army Special Forces Unit who has had extensive experience with using TCCC to treat combat casualties made the following recommendation: "Implement TCCC into all service medical training NOW" (Butler et al., 2006).

The article by Holcomb et al. (2006) on combat casualties in Iraq and Afghanistan documented that American forces in this conflict are experiencing the highest casualty survival rate in U.S. history. They identify four major factors as being responsible for this major achievement: (1) faster evacuation times, (2) TCCC, (3) better trained medics, and (4) better personal protective equipment.

In an article examining the causes of death in the first 82

Special Operations fatalities in the GWOT, Holcomb et al. (in press; a) found that two-thirds of the 12 fatalities whose wounds were potentially survivable might have been saved by proper application of TCCC principles.

Current Challenges

Rapid Transition of New TCCC Techniques and Technology

As noted above, all of the services in the U.S. military have in principle adopted the TCCC recommendations. To expedite the rapid transition of new technologies and management strategies to U.S. combatants, methods to ensure that deploying units have just-in-time equipping and training must be developed. Repeated reports from the battlefield emphasize the need to ensure that troops on the battlefield have not just the latest trauma care equipment, but also the training to use it successfully. The USSOCOM/USAISR TCCC Transition Initiative is one successful model of such a transition strategy (Butler and Holcomb, 2005), but others may serve as well.

TCCC Training for Nonmedical Personnel and Combat Lifesavers

Trauma care on the battlefield has historically been combat medic-centric, but many lifesaving interventions can and should be carried out by the casualties themselves and their nonmedical teammates as well. The challenge is to find the optimum strategy for ensuring that units on the battlefield have the right combination of medical skills distributed throughout unit personnel to maximize the probability that casualties will receive all of the life-saving care required as quickly as possible. Combat units will need to determine the mix of the three levels of TCCC training—nonmedical combatants, combat lifesavers, and combat medical personnel—that best serves their particular mission. There is a particular need to teach the TCCC concepts to tactical mission commanders and senior noncommissioned officers who will have to direct their unit's actions in a casualty scenario. Both Navy SEALs and Army Rangers have incorporated this item into their leadership raining (Butler, 2001; Jarvis et al., 2007).

TCCC Training for Deploying Physicians

Physicians in medical treatment facilities need to become familiar with the TCCC guidelines, since they may differ substantially from treatment methods used in the setting of an MTF. TCCC is a topic not addressed in medical school curricula and there is currently no program to assure that all deploying physicians are familiar with this approach to battlefield trauma care. If this familiarity does not exist, inappropriate direction and feedback may be given to front line providers.

Documenting Feedback from the Battlefield

First-responder feedback is critical to adjusting the TCCC guidelines based on current experiences. Although physicians and physician assistants have historically provided at least some formal feedback in the way of published case reports and case series, feedback from combat medical personnel has been limited and that from nonmedical first responders essentially absent. The recently established Joint Theater Trauma System (Eastridge et al., 2006) has made major advances in trauma care in the CENTCOM theater of operations. The Trauma Registry established as part of this effort could potentially address this issue successfully, but other methods of obtaining accurate, timely, first-responder input on how new TCCC equipment and strategies are working on the battlefield must be pursued as well. The TCCC Transition Initiative had some success in this area, but the data able to be collected from returning combat medical personnel was limited due to collection methodology, concerns for operational security, and medic availability. The first responder forums conducted by senior enlisted leaders in the combat medical community, such as those organized by SGM Harold Hill, MSG Ted Westmoreland, and MSG Harold Montgomery and presented at the last three Special Operations Medical Association conferences are excellent sources of input that should be encouraged and developed (Butler et al., 2006).

CoTCCC Resourcing

The CoTCCC noted above has been the body responsible for updating the TCCC guidelines since 2001. With the expanding use and documented success of these guidelines, the function of this committee becomes increasingly important, especially because accounts of battlefield experiences will be forthcoming from the present conflict for several years to come. This information needs to be assimilated and the guidelines adjusted as appropriate. This will be an ongoing, all-service effort that should be funded at an appropriate level. The CoTCCC leadership is working at the time this article is being written to secure the resources necessary to meet the demands generated by the success of the TCCC guidelines to date.

Optimal TCCC Training Strategies

There are a number of military and civilian courses that teach TCCC at present. The relative strengths and weaknesses of each course have not been well defined. Sohn et al.'s report (2006) of the 4-day program at Madigan noted that classroom scenarios, simulators, and live tissue were all part of the training. The authors stressed the importance of the live tissue training in overcoming the "frozen in place" reaction observed by the instructors in many of the course attendees when confronted for the first time with seemingly uncontrollable hemorrhage from a proximal femoral artery injury. The importance of live tissue training in preparing medics to care for combat casualties was also stressed by the presenters at a recent military lessons learned conference (Jarvis et al., 2007) and in first-responder forums (Butler et al., 2006). Carefully defining exactly what injuries to treat and what procedures to perform is an essential element of optimizing live tissue training. Establishment of a surgical airway is probably the procedure for which live tissue training is most beneficial. Other procedures for which live tissue training may be particularly helpful include application of tourniquets and hemostatic dressings, needle thoracostomy, chest tube insertion, and the use of direct pressure to stop severe bleeding (Brown, 2005a).

TCCC courses currently in use range from 2 to 11 days. The best combination of training techniques and the most cost-efficient methods of presenting TCCC concepts and skills remains to be determined, and TCCC courses may have to be customized for various units' particular needs.

Future Issues

New techniques and technologies may offer great opportunities for improvement of combat trauma care in the future. The CoTCCC will need to monitor the success of all currently recommended management strategies as additional information becomes available and to identify areas where modifications are needed or further research is necessary.

Modified configurations of the currently used HemCon and QuikClot have recently become available. (Chitoflex and the QuikClot Advanced Clotting Sponge) In addition, a number of promising new hemostatic agents have become available. The hemostatic agent options for first responders need to be re-evaluated in a comparative trial using appropriate animal models.

Recombinant factor VIIa has been a useful adjunct to stopping uncontrolled bleeding in animal models (Howes et al., 2007) and in medical treatment facilities (Martinowitz et al., 2004; Holcomb, 2005b). This agent may have a role in certain selected prehospital settings in military operations, especially those in areas such as Afghanistan, where evacuation times are often much longer than those in Iraq. The two most promising interventions for avoiding preventable deaths in the study by Holcomb et al. (2007a) besides proper performance of TCCC were faster CASEVAC and/or an IV hemostatic agent. The deployment strategy and the indications for the potential use of factor VIIa in the prehospital setting would both need to be carefully defined.

Optimum prehospital resuscitation strategies may continue to evolve. Hemoglobin-based oxygen carrying resuscitation fluids may become available in the near term. An evaluation of the relative merits of these agents as compared to the current Hextend resuscitation strategies will need to be performed if they are approved by the FDA. The aggressive administration of fresh frozen plasma in a 1:1 ratio with PRBCs has been shown to decrease mortality dramatically in a hospital setting (Holcomb et al., 2007b) and this modality may have a place in selected prehospital settings. Department of Defense researchers are pursuing a comprehensive approach to fluid resuscitation that will address the multiple factors that must be considered, including prevention or reversal of coagulopathies, oxygen-carrying considerations, duration of effect, and prevention of iatrogenically-induced rebleeding (Holcomb et al., 2007b). The principles and technologies that ensue from these investigations will apply mostly to care in medical treatment facilities but may be useful in some prehospital settings.

A common problem on the battlefield is management of severe pain in a casualty who is in shock or in danger of going into shock. Morphine and fentanyl are effective analgesics but are also cardiorespiratory depressants. Intranasal or IV ketamine or other medications that provide analgesia without depressing respiration and circulation should be evaluated for use by combat medics.

Acknowledgments

The authors express their appreciation to the many individuals who have contributed to this effort, in particular the Special Operations medical community and the individuals who serve on the Committee on Tactical Combat Casualty Care. Special thanks to RADM Tom Richards, RADM Bob Hufstader, RADM Steve Hart, CAPT Doug Freer, SFC Rob Miller, USA (Ret.), CAPT Brad Bennett, Dr. Howard Champion, SFC Dominique Greydanus, COL Steve Yevich, COL Dave Hammer, Mr. Dave Saren, Dr. Dale Uhler, Dr. Dave Callaway, Major Jeff Cain, Mr. Don Parsons, Dr. David Hoyt, Lt Col Mike Curriston, COL Rob Allen, COL Don Jenkins, LTC Kevin O'Connor, LTC Russ Kotwal, MAJ Chris Pappas, MSG Harold Montgomery, and HMCM Gary Welt.

References

Acheson EM, Kheirabadi BS, Dick EJ, Holcomb JB: Comparison of hemorrhage control agents applied to lethal extremity arterial hemorrhage in swine. J Trauma 2005; 59: 865–74.

Ahuja N, Ostomei TA, Rhee P, et al: Testing of modified zeolite hemostatic dressings in a large animal model of lethal groin injury. J Trauma 2006; 61: 1312–20.

Alam HB, Burris DB, DaCorta JA, Rhee P: Hemorrhage control in the battlefield: role of new hemostatic agents. Milit Med 2005; 170: 63–9.

Alam HB, Chen Z, Jaskille A, et al: Application of a zeolite hemostatic agent achieves 100% survival in a lethal model of complex groin injury in swine. J Trauma 2004; 56: 974–83.

Alam HB, Chen Z, Velmahos G, et al: Profound hypothermia is superior to ultraprofound hypothermia in improving survival in a swine model of lethal injuries. Surgery 2006; 140: 307–14.

Alam HB, Rhee P: New developments in fluid resuscitation. Surg Clin North Am 2007; 87: 55–72.

Alam HB, Uy GB, Miller D, et al: Comparative analysis of hemostatic agents in a swine model of lethal groin injury. J Trauma 2003; 54: 1077–82.

Alexander RH, Proctor HJ: Advanced Trauma Life Support 1993 Student Manual. American College of Surgeons; Chicago, 1993.

Allen RC, McAtee JM: Pararescue Medications and Procedures Manual. Air Force Special Operations Command Publication; January 1999.

Arthurs Z, Cuadrado D, Beekley, et al: The impact of hypothermia on trauma care at the 31st combat support hospital. Am J Surg 2006;191:610–14.

Baker MS: Advanced trauma life support: is it acceptable stand-alone training for military medicine? Milit Med 1994; 159: 581–90.

Barton ED, Epperson M, Hoyt DB, et al: Prehospital needle aspiration and tube thoracostomy in trauma victims: a six-year experience with aeromedical crews. J Emerg Med 1995; 13: 155–63.

Bateman C: Saving lives amid bullets and bombs. S Afr Med J 2006; 96:268–70.

Bellamy RF: How shall we train for combat casualty care? Milit Med 1987; 152: 617–21.

Ben-Abraham R, Gur I, Vater Y, Weinbroum AA: Intraosseous emergency access by physicians wearing full protective gear. Acad Emerg Med 2003; 10: 1407–10.

Bickell WH, Wall MJ, Pepe PE, et al: Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. N Engl J Med 1994; 331: 1105–9.

Bottoms M: Tactical Combat Casualty Care: Saving Lives on the Battlefield. Tip of the Spear (Command Publication of the U.S. Special Operations Command); June 2006, pp 34–5.

Bowden M: BlackHawk Down. New York, Atlantic Monthly Press, p 292, 1999.

Brimms FJ: Primary spontaneous tensionpneumothorax in a submariner at sea. Emerg Med J 2004; 21: 394–5.

Britten S, Palmer SH: Chest wall thickness may limit adequate drainage of tension pneumothorax by needle thoracentesis. J Accid Emerg Med 1996; 13: 426–7.

Britten S, Palmer SH, Snow TM: Needle thoracentesis in tension pneumothorax: insufficient cannula length and potential failure. Injury 1996; 27: 321–2.

Brown BD: Combat Trauma Training in Special Operations Forces. Commander, U.S. Special Operations Command Letter of December 9, 2005a.

Brown BD: Letter of Commendation to Army Medical Command. Commander, U.S. Special Operations Command Letter of August 17, 2005b.

Brown BD: Special Operations Combat Medic Critical Task List. Commander, U.S. Special Operations Command Letter of March 9, 2005c.

Bureau of Medicine and Surgery (Navy Surgeon General): Tactical Combat Casualty Care Training; message of 111622Z December 2006.

Burris D: USUHS Panel Letter on the safety of QuikClot, February 26, 2003.

Burris DG, FitzHarris JB, Holcomb JB, et al: Emergency War Surgery Manual, Third United States Revision, 2004.

Butler F: Tactical Combat Casualty Care: Combining good medicine with good tactics. J Trauma 2003; 54(Suppl): S2–3.

Butler FK: Tactical medicine training for SEAL mission commanders. Milit Med 2001; 166: 625–31.

Butler FK, Greydanus D, Holcomb J: Combat Evaluation of TCCC Techniques and

Equipment, 2005. USAISR Report 2006-01, November 2006.
Butler FK, Hagmann J (editors): Tactical management of urban warfare casualties in Special Operations. Milit Med 2000; 165(Suppl): 1–48.
Butler FK, Hagmann J, Butler EG: Tactical combat casualty care in Special Operations. Milit Med 1996; 161(Suppl): 1–16.
Butler FK, Holcomb JB: The Tactical Combat Casualty Care Transition Initiative. U.S. Army Medical Department Journal, April-June 2005.
Butler FK, Smith DJ: Tactical Management of Diving Casualties in Special Operations. In: Forty-Sixth Workshop of the Undersea and Hyperbaric Medical Society. Kensington, MD, Undersea and Hyperbaric Medical Society, 1996.
Butler KL, Best IM, Weaver WL, Bumpers HL: Pulmonary artery injury and cardiac tamponade after needle decompression of a suspected tension pneumothorax. J Trauma 2003; 54: 610–11.
Calkins MD, Fitzgerald G, Bentley TB, et al: Intraosseous infusion devices: a comparison for potential use in Special Operations. J Trauma 2000; 48: 1068–74.
Carr ME: Monitoring of hemostasis in combat trauma patients. Milit Med 2004; 169(Suppl): 11–15.
Clifford CC: Treating traumatic bleeding in a combat setting. Milit Med 2004; 169: 8–10.
Cloonan CC: Treating traumatic bleeding in a combat setting. Milit Med 2004; 168: 8–10.
Covey DC: Combat orthopedics: a view from the trenches. J Am Acad Orthop Surg 2006; 14: S10–17.
Cullinane DC, Morris JA, Bass JG, Rutherford EJ: Needle thoracostomy may not be indicated in the trauma patient. Injury 2001; 32: 749–52.
Davis DP, Pettit K, Rom CD, et al: The safety and efficacy of prehospital needle and tube thoracostomy by aeromedical personnel. Prehosp Emerg Care 2005; 9: 191–7.
DeLorenzo RA: Medic for the millennium: the U.S. Army 91W health care specialist. Milit Med 2001; 166: 685–8.
Donham B, Otten M: Hypotensive resuscitation. J Special Oper Med 2006; 6: 35–8.
Dubick MA, Holcomb JB: A review of intraosseous vascular access: current status and military application. Milit Med 2000; 165: 552–9.
Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB: Trauma system development in a theater of war: experiences from Operation Iraqi Freedom and Operation Enduring Freedom. J Trauma 2006; 1366–73.
Eckstein M, Suyehara D: Needle thoracostomy in the prehospital setting. Prehosp Emerg Care 1998; 2: 132–5.
Fries D, Innerhofer P, Schobersberger W: Coagulation management in trauma patients. Curr Opin Anaesthesiol 2002; 15: 217–23.
Givens ML, Ayotte K, Manifold C: Needle thoracostomy: implications of computed tomography chest wall thickness. Acad Emerg Med 2004; 11: 795–6.
Gonzalez EA, Moore FA, Holcomb JB, et al: Fresh frozen plasma should be given earlier to patients requiring massive transfusion. J Trauma 2007; 62: 112–19.
Gresham J: The Year in Military and Veteran's Medicine, 2005–2006. Washington, DC, Department of Veterans Affairs.
Grissom CK, Weaver LK, Clemmer TP, Morris AH: Theoretical advantage of oxygen treatment for combat casualties during medical evacuation at high altitude. J Trauma 2006; 61: 461–7.
Guyette FX, Rittenberger JC, Platt T, et al: Feasibility of basic emergency medical technicians to perform selected advanced life support interventions. Prehosp Emerg Care 2006; 10: 518–21.
Handrigan MT, Bentley TB, Oliver JD, Tabaku LS, Burge JR, Atkins JL: Choice of fluid influences outcome in prolonged hypotensive resuscitation after hemorrhage in awake rats. Shock 2005; 23: 337–43.
Heiskell LE, Carmona RH: Tactical emergency medical services: an emerging subspecialty in emergency medicine. Ann Emerg Med 1994; 23: 778–85.
Hell K: Characteristics of the ideal antibiotic for prevention of wound sepsis among military forces in the field. Rev Infect Dis 1991; 13(Suppl): S164–9.
Heng K, Bystrzycki A, Fitzgerald M, et al: Complications of intercostal catheter insertion using EMST techniques for chest trauma. ANZ J Surg 2004; 74: 420–3.
Henry KH: Naval Operational Medical Lessons Learned After Action Report of August 24, 2005, CDR Item 739. Pensacola, FL, Naval Operational Medicine Institute.
Henshaw D: Tension pneumothoraces. Lancet 2005; 365: 2243.
Holcomb JB: The 2004 Fitts Lecture: current perspectives on combat casualty care. J Trauma 2005a; 59: 990–1002.
Holcomb JB: Use of recombinant activated factor VII to treat the acquired coagulopathy of trauma. J Trauma 2005b; 58: 1298–1303.
Holcomb JB: Fluid resuscitation in modern combat casualty care: lessons learned from Somalia. J Trauma 2003; 54: S46–51.
Holcomb JB, Caruso J, Pearse L, et al: Causes of death in Special Operations forces in the Global War on Terror. Ann Surg 2007a; 245: 986–91.
Holcomb JB, Jenkins D, Rhee P, et al: Damage control resuscitation: directly addressing the early coagulopathy of trauma. J Trauma 2007b; 62: 307–10.
Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF: Understanding combat casualty care statistics. J Trauma 2006; 60: 397–401.
Holcomb JH, Kerr ST, Macaitis JM, et al: Needle vs tube thoracostomy in a swine model of traumatic tension pneumothorax. J Trauma (in press).
Hostage GM: USSOCOM visit to the Pararescue medical course at Kirtland AFB September 15–16, 2005, Air Force Education and Training Command Letter 8 September 2005.
Howes DW, Stratford A, Stirling M, Ferri CC, Bardell T: Administration of recombinant factor VI: Ia decreases blood loss after blunt trauma in noncoagulopathic pigs. J Trauma 2007; 62: 311–15.
Husum H, Olsen T, Murad M, Wisborg T, Gilbert M: Preventing post-injury hypothermia during prolonged prehospital evacuation. Phehospital Disaster Med 2002; 17: 23–6.
Isbye DL, Nielson SL: Intraosseous access in adults - an alternative if conventional vascular access is difficult. Ugeskr Laeger 2006; 168: 2793–7.
Jarvis C, Kotwal R, Erickson J, Trawinski M: Lessons Learned in Operation Enduring Freedom and Operation Iraqi Freedom: Uniformed Services Academy of Family Physicians presentation, March 13, 2007.
Johnson DL, Findlay J, Macnab AJ, Susak L: Cadaver testing to validate design criteria of an adult intraosseous infusion system. Milit Med 2005; 170: 251–7.
Jones R, Hollingsworth J: Tension pneumothoraces not responding to needle thoracentesis. Emerg Med J 2002; 19: 176–7.
Kentner R, Safar P, Prueckner S, et al: Titrated hypertonic/hyperoncotic solution for hypotensive fluid resuscitation during uncontrolled hemorrhagic shock in rats. Resuscitation 2005; 65: 87–95.
Kheirabadi BS, Acheson EM, Deguzman R, et al: The potential utility of fibrin sealant dressing in repair of vascular injury in swine. J Trauma 2007; 62: 94–103.
Kheirabadi BS, Acheson EM, Deguzman R, et al: Hemostatic efficacy of two advanced dressings in an aortic hemorrhage model in swine. J Trauma 2005; 59: 25–34.
Kiley KC: Operational Needs Statement for Medical Simulation Training Centers for Combat Lifesavers and Tactical Combat Casualty Care Training: Army Surgeon General Letter DASG-ZA of September 1, 2005a.
Kiley KC: Army Surgeon General ALARACT 066-2005, March 30, 2005b.
Kiley KC: HemCon Dressing (HC; chitosan bandage) for deployed Army personnel: Army Surgeon General Letter of July 20, 2003c.
King RB, Filips D, Blitz S, Logsetty S: Evaluation of possible tourniquet systems for use in the Canadian forces. J Trauma 2006; 60: 1061–71.
Kotwal R, O'Connor KC, Johnson TR, et al: A novel pain management strategy for combat casualty care. Ann Emerg Med 2004; 44: 121–7.
Krausz MM: Resuscitation Strategies in the Israeli Army: Presentation to the Institute of Medicine Committee on Fluid Resuscitation for Combat Casualties, September 17, 1998.
Kucisec-Tepes N, Bejuk D, Kosuta D: Characteristics of war wound infection. Acta Med Croatica 2006; 60: 353–63.
Lakstein D, Blumenfeld A, Sokolov T, et al: Tourniquets for hemorrhage control on the battlefield: a 4-year accumulated experience. J Trauma 2003; 54: S221–5.
LaRocco BG, Wang HE: Intraosseous infusion. Prehosp Emerg Care 2003; 7: 280–5.
Leigh-Smith S, Harris T: Tension pneumothorax— time for a re-think? Emerg Med J 2005; 22: 8–16.
Mabry RL: Tourniquet use on the battlefield. Milit Med 2006; 171: 352–6.
Mabry RL, Holcomb JB, Baker AM, et al: United States Army Rangers in Somalia: an analysis of combat casualties on an urban battlefield. J Trauma 2000; 49: 515–29.
Malish RG: The preparation of a Special Forces company for pilot recovery. Milit Med 1999; 164: 881–4.
Martin JE, Mehta R, Aarabi B, et al: Intracranial insertion of a nasopharyngeal airway in a patient with craniofacial trauma. Milit Med 2004; 169: 496–7.
Martinowitz U, Zaarur M, Yaron BL, Blumendeld A, Martinovits G: Treating traumatic bleeding in a combat setting: possible role of recombinant activated factor VV. Milit Med 2004; 169(Suppl): S16–18.
Massarutti D, Trillo G, Berlot G, et al: Simple thoracostomy in prehospital trauma management is safe and effective: a 2-year experience by helicopter emergency medical crews. Eur J Emerg Med 2006; 13: 276–80.
Maughon JS: An inquiry into the nature of wounds resulting in killed in action in Vietnam. Milit Med 1970; 135: 8–13.
Mazurek MT, Ficke JR: The scope of wounds encountered in casualties from the Global War on Terrorism: from the battlefield to the tertiary treatment facility. J Am Acad Orthop Surg 2006; 14: S18–23.
McCarthy M: US military revamps combat medic training and care. Lancet 2003; 361: 494–5.
McDevitt I: Tactical Medicine. Boulder, CO, Paladin Press, 2001.
McManus J, Hurtado T, Pusateri A, Knoop KJ: A case series describing thermal injury

resulting from zeolite use for hemorrhage control in combat operations. Prehospital Emergency Care 2007; 11: 67–71.
McPherson JJ, Feigin DS, Bellamy RF: Prevalence of tension pneumothorax in fatally wounded combat casualties. J Trauma 2006; 60: 573–8.
McRaven WH: Spec Ops: case studies in Special Operations warfare theory and Practice. Novato, CA, Presidio Press,1996.
McSwain NE, Frame S, Paturas JL, eds: Prehospital Trauma Life Support Manual. Akron, Mosby, Fourth Edition; 1999.
McSwain NE, Frame S, Salome JP (editors): Prehospital Trauma Life Support Manual, Ed 5 (second printing). Akron, OH, Mosby, 2003.
McSwain NE, Salome JP (editors): Prehospital Trauma Life Support Manual, Ed 6. Akron, OH, Mosby, 2006.
Mellor SG, Cooper GJ, Bowyer GW: Efficacy of delayed administration of benzyl penicillin in the control of infection of penetrating soft tissue injuries in war. J Trauma 1996; 40: S128–34.
Miller DD, Guimond G, Hostler DP, Platt T, Wang HE: Feasibility of sternal intraosseous access by emergency medical technician students. Prehosp Emerg Care 2005; 9: 73–8.
Mucclarone JJ, Llewellyn CH, Wightman J: Tactical combat casualty care in the assault on Punta Patilla airfield. Milit Med 2006; 171: 687–90.
Murray CK, Roop SA, Hospenthal DR, et al: Bacteriology of war wounds at the time of injury. Milit Med 2006; 171: 826–9.
Navein J, Coupland R, Dunn R: The tourniquet controversy. J Trauma 2003; 54: S219–20.
Navy Operational Medical Lesson Learned 8177: QuikClot Application Method.
Navy Operational Medical Lesson Learned 39582: Medical Training.
Navy Operational Medical Lesson Learned 40329: Training Marines.
Navy Operational Medical Lesson Learned 41655: Tension Pneumothorax.
Naylor S: Not a Good Day to Die. New York; Berkley Books; 2005.
Neuffer MC, McDivitt J, Rose D, et al: Hemostatic dressings for the first responder: a review. Milit Med 2004; 169: 716–20.
O'Connor KO, Butler FK: Antibiotics in tactical combat casualty care. Milit Med 2003; 168: 911–14.
Pappas CG: The Ranger medic. Milit Med 2001; 166: 394–400.
Peng RY, Bongard FS: Hypothermia in trauma patients. J Am Coll Surg 1999; 188: 685–96.
Pusateri AE, Delgado AV, Dick EJ, et al: Application of a granular mineral-based hemostatic agent (QuikClot) to reduce blood loss after grade V liver injuries in swine. J Trauma 2004; 57: 555–62.
Pusateri AE, Holcomb JB, Kheirabadi BS, et al: Making sense of the preclinical literature on advanced hemostatic products. J Trauma 2006; 60: 674–82.
Pusateri AE, Modrow HE, Harris RA, et al: Advanced hemostatic dressing development program: animal model selection criteria and results of a study of nine hemostatic dressings in a model of severe large venous hemorrhage and hepatic injury in swine. J Trauma 2003; 53: 518–26.
Rhee P, Brown C, Martin M, et al: QuikClot use in trauma for hemorrhage control: case series of 103 documented uses. J Trauma (in press).
Richards TR: Tactical Combat Casualty Care Training. Commander, Naval Special Warfare Command Letter 1500 Series 04/0341 of April 9, 1997.
Ruterbusch VL, Swiergosz MJ, Montgomery LD, Hopper KW, Gerth WA: ONR/MARSYSCOM evaluation of self-applied tourniquets for combat applications. Navy Experimental Diving Unit Technical Report TR 05-15, November 2005.
Sohn VY, Miller JP, Koeller CA, et al: From the combat medic to the forward surgical team: the Madigan Model for improving trauma readiness of brigade combat teams fighting the Global War on Terror. J Surg Res 2007: 138: 25–31.
Sondeen JL, Coppes VG, Holcomb JB: Blood pressure at which rebleeding occurs after resuscitation in swine with aortic injury. J Trauma 2003a; 54: S110–17.
Sondeen JL, Pusateri AE, Coppes VG, Gaddy CE, Holcomb JB: Comparison of 10 different hemostatic dressings in an aortic injury. J Trauma 2003b; 54: 280–5.
Starnes BW, Beekley AC, Sebesta JA, Anderson CA, Rush RM: Extremity vascular injuries on the battlefield: tips for surgeons deploying to war. J Trauma 2006; 60: 432–42.
Tarpey M: Tactical combat casualty care in Operation Iraqi Freedom. U.S. Army Medical Department Journal 2005, April-June, pp 38–41.
U.S. Central Command message 061715Z January 2005. Program.
U.S. Coast Guard message 221752Z November 2006: Tactical Medical Response
U.S. Marine Corps Message 02004Z August 2006: Tactical Combat Casualty Care (TCCC) and Combat Lifesaver (CLS) Fundamentals, Philosophies, and Guidance.
U.S. Special Operations Command message 222016Z March 2005: Tactical Combat Casualty Care Training and Equipment. Washington, DC, Headquarters, U.S. Marine Corps, 2005.
Vardi A, Berkenstadt H, Levin I, Bentencur A, Ziv A: Intraosseous vascular access in the treatment of chemical warfare casualties assessed by advanced simulation: proposed alteration of treatment protocol. Anesth Analg 2004; 98: 1753–8.
Vinson ED: Improvised chest tube drain for decompression of an acute tension pneumothorax. Milit Med 2004; 169: 403–5.
Walters TJ, Kauvar DS, Baer DG, Holcomb JB: Battlefield tourniquets—modern combat lifesavers. U.S. Army Medical Department Journal, April-June, 2005a, pp 42–3.
Walters TJ, Mabry RL: Issues related to the use of tourniquets on the battlefield. Milit Med 2005; 170: 770–775.
Walters TJ, Wenke JC, Greydanus DJ, Kauver DS, Baer DG: Laboratory evaluation of battlefield tourniquets in human volunteers. USAISR Report 2005-05, September 2005b.
Watts DD, Trask A, Soeken K, et al: Hypothermic coagulopathy in trauma: effect of varying levels of hypothermia on enzyme speed, platelet function, and fibrinolytic activity. J Trauma 1998; 44: 846–54.
Waydhess C, Sauerland S: Pre-hospital pleural decompression and chest tube placement after blunt trauma. Resuscitation 2007; 72: 11–25.
Wedmore I, McManus JG, Pusateri AE, Holcomb JB: A special report on the chitosan-based hemostatic dressing: experience in current combat operations. J Trauma 2006; 60: 655–8.
Wedmore IS, Johnson T, Czarnik J, Hendrix V: Pain management in the wilderness and austere environments. J Special Oper Med 2006; 6: 56–64.
Welling DR, Burris DG, Hutton JE, Minken SL, Rich NM: A balance approach to tourniquet use: lessons learned and relearned. J Am Coll Surg 2006; 203: 106–15.
West BC, Bentley R, Place RJ: In-flight transfusion of packed red blood cells on a combat search and rescue mission: a case report from Operation Enduring Freedom. Milit Med 2004; 169: 181–3.
Winkenwerder W: ASDHA Policy Letter on Hypothermia Prevention and Treatment, February 16, 2006.
Wolberg AS, Meng ZH, Monroe DM III, Hoffman M: A systematic evaluation of the effect of temperature on coagulation enzyme activity and platelet function. J Trauma 2004; 56: 1221–8.
Wolff LH, Adkins TF: Tourniquet problems in war injuries. Bull U.S. Army Medical Department 1945, pp 77–85.
Wright FL, Hua HT, Velmahos G, et al: Intracorporeal use of the hemostatic agent QuickClot in a coagulopathic patient with combined thoracoabdominal penetrating trauma. J Trauma 2004; 56: 205–8.
Wright J, Kalns J, Wolf EA, et al: Thermal injury resulting from application of a granular mineral hemostatic agent. J Trauma 2004; 57: 224–30.